

In the another preferred embodiment, the peptide O-linked glycans are remodeled to display a sialylated Lewis X antigen. In this embodiment, the glycan structure described in Formula 2 is remodeled to have the following moieties:

- 5 X^2 is β -SA;
 X^{10} is Fuc or β -GlcNAc(Fuc)-Gal-SA;
 f and n = 1;
 m = 0.

This embodiment is particularly advantageous when the peptide which is being remodeled is most effective when targeted to a selectin molecule and cells exhibiting the same.

- 10 In a yet another preferred embodiment, the peptide O-linked glycans are remodeled to contain a conjugated moiety. The conjugated moiety may be a PEG molecule, another peptide, a small molecule such as a drug, among others. In this embodiment, the glycan structure described in Formula 2 is remodeled to have the following moieties:

- 15 X^2 is β -SA-R;
 f = 1;
 n and m = 0;
 where R is the conjugate group.

This embodiment is useful for conjugating the peptide to PEG molecules that will slow the clearance of the peptide from the patient's bloodstream, to peptides that will target both
 20 peptides to a specific tissue or cell or to another peptide of complementary therapeutic use.

- It will be clear to one of skill in the art that the invention is not limited to the preferred glycan molecules described above. The preferred embodiments are only a few of the many useful glycan molecules that can be made using the remodeling methods of the invention. Those skilled in the art will know how to design other useful glycans once armed with the
 25 present invention.

In the first exemplary embodiment, the peptide is expressed in a CHO (Chinese hamster cell line) according to methods well known in the art. When a peptide with O-linked glycan consensus sites is expressed and secreted from CHO cells, the majority of the O-linked glycans will often have the structure, in the terms of Formula 2,

- 30 $X^2 = \beta$ -SA;
 f = 1;

m and n = 0.

Therefore, most of the glycans in CHO cells do not require remodeling in order to be acceptable for use in a human patient. In an exemplary embodiment, the O-linked glycans of a peptide expressed and secreted from a CHO cell are remodeled to contain a sialylated Lewis X structure by contacting the glycans with a glycosyltransferase specific for the GalNAc acceptor moiety and the fucose donor moiety in the presence of nucleotide-fucose. This process is illustrated on N-linked glycans in Figure 11 and Example 39.

In other exemplary embodiments, the peptide is expressed in insect cells such as sf9 according to methods well known in the art. When a peptide having O-linked glycan consensus sites is expressed and secreted from most sf9 cells, the majority of the O-linked glycans have the structure, in the terms of Formula 2:

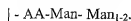
$$X^2 = H;$$

$$f = 0 \text{ or } 1;$$

$$n \text{ and } m = 0.$$

See, for example, Marchal et al., (2001, Biol. Chem. 382:151-159). In one exemplary embodiment, the O-linked glycan on a peptide expressed in an insect cell is remodeled to a humanized glycan by contacting the glycans with a glycosyltransferase specific for a GalNAc acceptor molecule and a galactose donor molecule in the presence of nucleotide-Gal; and then contacting the glycans with a glycosyltransferase specific for a Gal acceptor molecule and a SA donor molecule in the presence of nucleotide-SA. In another exemplary embodiment, the O-linked glycans are remodeled further from the humanized form to the sialylated Lewis X form by further contacting the glycans with a glycosyltransferase specific for a GalNAc acceptor molecule and a fucose donor molecule in the presence of nucleotide-fucose.

In yet another exemplary embodiment, the peptide is expressed in fungal cells, in particular *S. cerevisiae* cells, according to methods well known in the art. When a peptide with O-linked glycans consensus sites is expressed and secreted from *S. cerevisiae* cells, the majority of the O-linked glycans have the structure:



See Gemmill and Trimble (1999, Biochim. Biophys. Acta 1426:227-237). In order to remodel these O-linked glycans for use in human, it is preferable that the glycan be cleaved at the amino acid level and rebuilt from there.

In an exemplary embodiment, the glycan is the O-linked glycan on a peptide expressed in a fungal cell and is remodeled to a humanized glycan by contacting the glycan with an endoglycosylase specific for an amino acid - GalNAc bond; and then contacting the glycan with a glycosyltransferase specific for a O-linked consensus site and a GalNAc donor molecule in the presence of nucleotide-GalNAc; contacting the glycan with a glycosyltransferase specific for a GalNAc acceptor molecule and a galactose donor molecule in the presence of nucleotide-Gal; and then contacting the glycans with a glycosyltransferase specific for a Gal acceptor molecule and a SA donor molecule in the presence of nucleotide-SA.

Alternately, in another exemplary embodiment, the glycan is the O-linked glycan on a peptide expressed in a fungal cell and is remodeled to a humanized glycan by contacting the glycan with an protein O-mannose β -1,2-N-acetylglucosaminyltransferase (POMGnTII) in the presence of GlcNAc-nucleotide; then contacting the glycan with an galactosyltransferase in the presence of nucleotide-Gal; and then contracting the glycan with an sialyltransferase in the presence of nucleotide-SA.

In another exemplary embodiment, the peptide is expressed in bacterial cells, in particular *E. coli* cells, according to methods well known in the art. When a peptide with an O-linked glycan consensus site is expressed in *E. coli* cells, the O-linked consensus site will not be glycosylated. In this case, the desired glycan molecule must be built out from the peptide backbone in a manner similar to that describe for *S. cerevisiae* expression above. Further, when a peptide having an O-linked glycan is expressed in a eukaryotic cell without the proper leader sequences to direct the nascent peptide to the golgi apparatus, the mature peptide is likely not to be glycosylated. In this case as well, an O-linked glycosyl structure may be added to the peptide by building out the glycan directly from the peptide O-linked consensus site. Further, when a protein is chemically modified with a sugar moiety, it can also be remodeled as described herein.

These examples are meant to illustrate the invention, and not to limit it in any way. One of skill in the art will appreciate that the steps taken in each example may in some

circumstances be performed in a different order to achieve the same result. One of skill in the art will also understand that a different set of steps may also produce the same resulting glycan. Further, the preferred remodeled glycan is by no means specific to the expression system that the peptide is expressed in. The remodeled glycans are only illustrative and one of skill in the art will know how to take the principles from these examples and apply them to peptides produced in different expression systems to generate glycans not specifically described herein.

C. Glycoconjugation, in general

The invention provides methods of preparing a conjugate of a glycosylated or an unglycosylated peptide. The conjugates of the invention are formed between peptides and diverse species such as water-soluble polymers, therapeutic moieties, diagnostic moieties, targeting moieties and the like. Also provided are conjugates that include two or more peptides linked together through a linker arm, i.e., multifunctional conjugates. The multifunctional conjugates of the invention can include two or more copies of the same peptide or a collection of diverse peptides with different structures, and/or properties.

The conjugates of the invention are formed by the enzymatic attachment of a modified sugar to the glycosylated or unglycosylated peptide. The modified sugar, when interposed between the peptide and the modifying group on the sugar becomes what is referred to herein as "an intact glycosyl linking group." Using the exquisite selectivity of enzymes, such as glycosyltransferases, the present method provides peptides that bear a desired group at one or more specific locations. Thus, according to the present invention, a modified sugar is attached directly to a selected locus on the peptide chain or, alternatively, the modified sugar is appended onto a carbohydrate moiety of a peptide. Peptides in which modified sugars are linked to both a peptide carbohydrate and directly to an amino acid residue of the peptide backbone are also within the scope of the present invention.

In contrast to known chemical and enzymatic peptide elaboration strategies, the methods of the invention make it possible to assemble peptides and glycopeptides that have a substantially homogeneous derivatization pattern; the enzymes used in the invention are generally selective for a particular amino acid residue or combination of amino acid residues of the peptide or particular glycan structure. The methods are also practical for large-scale

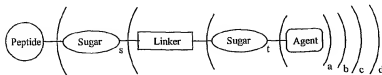
production of modified peptides and glycopeptides. Thus, the methods of the invention provide a practical means for large-scale preparation of peptides having preselected substantially uniform derivatization patterns. The methods are particularly well suited for modification of therapeutic peptides, including but not limited to, peptides that are incompletely glycosylated during production in cell culture cells (*e.g.*, mammalian cells, insect cells, plant cells, fungal cells, yeast cells, or prokaryotic cells) or transgenic plants or animals.

The methods of the invention also provide conjugates of glycosylated and unglycosylated peptides with increased therapeutic half-life due to, for example, reduced clearance rate, or reduced rate of uptake by the immune or reticuloendothelial system (RES). Moreover, the methods of the invention provide a means for masking antigenic determinants on peptides, thus reducing or eliminating a host immune response against the peptide. Selective attachment of targeting agents can also be used to target a peptide to a particular tissue or cell surface receptor that is specific for the particular targeting agent. Moreover, there is provided a class of peptides that are specifically modified with a therapeutic moiety.

1. The Conjugates

In a first aspect, the present invention provides a conjugate between a peptide and a selected moiety. The link between the peptide and the selected moiety includes an intact glycosyl linking group interposed between the peptide and the selected moiety. As discussed herein, the selected moiety is essentially any species that can be attached to a saccharide unit, resulting in a "modified sugar" that is recognized by an appropriate transferase enzyme, which appends the modified sugar onto the peptide. The saccharide component of the modified sugar, when interposed between the peptide and a selected moiety, becomes an "intact glycosyl linking group." The glycosyl linking group is formed from any mono- or oligo-saccharide that, after modification with a selected moiety, is a substrate for an appropriate transferase.

The conjugates of the invention will typically correspond to the general structure:



in which the symbols a, b, c, d and s represent a positive, non-zero integer; and t is either 0 or a positive integer. The "agent" is a therapeutic agent, a bioactive agent, a detectable label, water-soluble moiety or the like. The "agent" can be a peptide, e.g., enzyme, antibody, antigen, etc. The linker can be any of a wide array of linking groups, *infra*. Alternatively, the linker may be a single bond or a "zero order linker." The identity of the peptide is without limitation. Exemplary peptides are provided in Figure 28.

In an exemplary embodiment, the selected moiety is a water-soluble polymer. The water-soluble polymer is covalently attached to the peptide via an intact glycosyl linking group. The glycosyl linking group is covalently attached to either an amino acid residue or a glycosyl residue of the peptide. Alternatively, the glycosyl linking group is attached to one or more glycosyl units of a glycopeptide. The invention also provides conjugates in which the glycosyl linking group is attached to both an amino acid residue and a glycosyl residue.

In addition to providing conjugates that are formed through an enzymatically added intact glycosyl linking group, the present invention provides conjugates that are highly homogenous in their substitution patterns. Using the methods of the invention, it is possible to form peptide conjugates in which essentially all of the modified sugar moieties across a population of conjugates of the invention are attached to multiple copies of a structurally identical amino acid or glycosyl residue. Thus, in a second aspect, the invention provides a peptide conjugate having a population of water-soluble polymer moieties, which are covalently linked to the peptide through an intact glycosyl linking group. In a preferred conjugate of the invention, essentially each member of the population is linked via the glycosyl linking group to a glycosyl residue of the peptide, and each glycosyl residue of the peptide to which the glycosyl linking group is attached has the same structure.

Also provided is a peptide conjugate having a population of water-soluble polymer moieties covalently linked thereto through an intact glycosyl linking group. In a preferred embodiment, essentially every member of the population of water soluble polymer moieties is linked to an amino acid residue of the peptide via an intact glycosyl linking group, and each amino acid residue having an intact glycosyl linking group attached thereto has the same structure.

The present invention also provides conjugates analogous to those described above in which the peptide is conjugated to a therapeutic moiety, diagnostic moiety, targeting moiety,

toxin moiety or the like via an intact glycosyl linking group. Each of the above-recited moieties can be a small molecule, natural polymer (e.g., peptide) or synthetic polymer.

In an exemplary embodiment, interleukin-2 (IL-2) is conjugated to transferrin via a bifunctional linker that includes an intact glycosyl linking group at each terminus of the PEG moiety (Scheme 1). For example, one terminus of the PEG linker is functionalized with an intact sialic acid linker that is attached to transferrin and the other is functionalized with an intact GalNAc linker that is attached to IL-2.

In another exemplary embodiment, EPO is conjugated to transferrin. In another exemplary embodiment, EPO is conjugated to glial derived neurotropic growth factor (GDNF). In these embodiments, each conjugation is accomplished via a bifunctional linker that includes an intact glycosyl linking group at each terminus of the PEG moiety, as aforementioned. Transferrin transfers the protein across the blood brain barrier.

As set forth in the Figures appended hereto, the conjugates of the invention can include intact glycosyl linking groups that are mono- or multi-valent (e.g., antennary structures), see, Figures 14-22. The conjugates of the invention also include glycosyl linking groups that are O-linked glycans originating from serine or threonine (Figure 11). Thus, conjugates of the invention include both species in which a selected moiety is attached to a peptide via a monovalent glycosyl linking group. Also included within the invention are conjugates in which more than one selected moiety is attached to a peptide via a multivalent linking group. One or more proteins can be conjugated together to take advantage of their biophysical and biological properties.

In a still further embodiment, the invention provides conjugates that localize selectively in a particular tissue due to the presence of a targeting agent as a component of the conjugate. In an exemplary embodiment, the targeting agent is a protein. Exemplary proteins include transferrin (brain, blood pool), human serum (HS)-glycoprotein (bone, brain, blood pool), antibodies (brain, tissue with antibody-specific antigen, blood pool), coagulation Factors V-XII (damaged tissue, clots, cancer, blood pool), serum proteins, e.g., α -acid glycoprotein, fetuin, α -fetal protein (brain, blood pool), β 2-glycoprotein (liver, atherosclerosis plaques, brain, blood pool), G-CSF, GM-CSF, M-CSF, and EPO (immune stimulation, cancers, blood pool, red blood cell overproduction, neuroprotection), and albumin (increase in half-life).

In addition to the conjugates discussed above, the present invention provides methods for preparing these and other conjugates. Thus, in a further aspect, the invention provides a method of forming a covalent conjugate between a selected moiety and a peptide.

Additionally, the invention provides methods for targeting conjugates of the invention to a particular tissue or region of the body.

In exemplary embodiments, the conjugate is formed between a water-soluble polymer, a therapeutic moiety, targeting moiety or a biomolecule, and a glycosylated or non-glycosylated peptide. The polymer, therapeutic moiety or biomolecule is conjugated to the peptide via an intact glycosyl linking group, which is interposed between, and covalently linked to both the peptide and the modifying group (e.g., water-soluble polymer). The method includes contacting the peptide with a mixture containing a modified sugar and a glycosyltransferase for which the modified sugar is a substrate. The reaction is conducted under conditions sufficient to form a covalent bond between the modified sugar and the peptide. The sugar moiety of the modified sugar is preferably selected from nucleotide sugars, activated sugars and sugars, which are neither nucleotides nor activated.

In one embodiment, the invention provides a method for linking two or more peptides through a linking group. The linking group is of any useful structure and may be selected from straight-chain and branched chain structures. Preferably, each terminus of the linker, which is attached to a peptide, includes a modified sugar (i.e., a nascent intact glycosyl linking group).

In an exemplary method of the invention, two peptides are linked together via a linker moiety that includes a PEG linker. The construct conforms to the general structure set forth in the cartoon above. As described herein, the construct of the invention includes two intact glycosyl linking groups (i.e., $s + t = 1$). The focus on a PEG linker that includes two glycosyl groups is for purposes of clarity and should not be interpreted as limiting the identity of linker arms of use in this embodiment of the invention.

Thus, a PEG moiety is functionalized at a first terminus with a first glycosyl unit and at a second terminus with a second glycosyl unit. The first and second glycosyl units are preferably substrates for different transferases, allowing orthogonal attachment of the first and second peptides to the first and second glycosyl units, respectively. In practice, the (glycosyl)¹-PEG-(glycosyl)² linker is contacted with the first peptide and a first transferase

for which the first glycosyl unit is a substrate, thereby forming (peptide)¹-(glycosyl)¹-PEG-(glycosyl)². The first transferase and/or unreacted peptide is then optionally removed from the reaction mixture. The second peptide and a second transferase for which the second glycosyl unit is a substrate are added to the

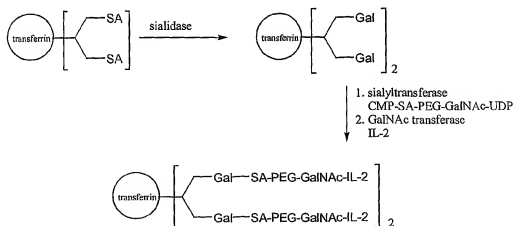
(peptide)¹-(glycosyl)¹-PEG-(glycosyl)² conjugate, forming (peptide)¹-(glycosyl)¹-PEG-(glycosyl)²-(peptide)². Those of skill in the art will appreciate that the method outlined above is also applicable to forming conjugates between more than two peptides by, for example, the use of a branched PEG, dendrimer, poly(amino acid), polysaccharide or the like.

As noted previously, in an exemplary embodiment, interleukin-2 (IL-2) is conjugated to transferrin via a bifunctional linker that includes an intact glycosyl linking group at each terminus of the PEG moiety (Scheme 1). The IL-2 conjugate has an *in vivo* half-life that is increased over that of IL-2 alone by virtue of the greater molecular size of the conjugate.

Moreover, the conjugation of IL-2 to transferrin serves to selectively target the conjugate to the brain. For example, one terminus of the PEG linker is functionalized with a CMP-sialic acid and the other is functionalized with an UDP-GalNAc. The linker is combined with IL-2 in the presence of a GalNAc transferase, resulting in the attachment of the GalNAc of the linker arm to a serine and/or threonine residue on the IL-2.

In another exemplary embodiment, transferrin is conjugated to a nucleic acid for use in gene therapy.

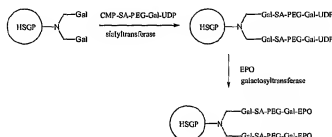
Scheme 1



The processes described above can be carried through as many cycles as desired, and is not limited to forming a conjugate between two peptides with a single linker. Moreover, those of skill in the art will appreciate that the reactions functionalizing the intact glycosyl linking groups at the termini of the PEG (or other) linker with the peptide can occur simultaneously in the same reaction vessel, or they can be carried out in a step-wise fashion. When the reactions are carried out in a step-wise manner, the conjugate produced at each step is optionally purified from one or more reaction components (e.g., enzymes, peptides).

A still further exemplary embodiment is set forth in Scheme 2. Scheme 2 shows a method of preparing a conjugate that targets a selected protein, e.g., EPO, to bone and increases the circulatory half-life of the selected protein.

Scheme 2

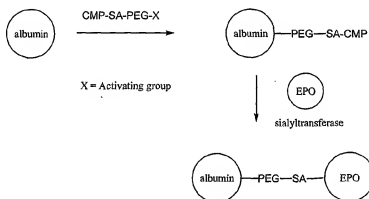


The use of reactive derivatives of PEG (or other linkers) to attach one or more peptide moieties to the linker is within the scope of the present invention. The invention is not limited by the identity of the reactive PEG analogue. Many activated derivatives of poly(ethylene glycol) are available commercially and in the literature. It is well within the abilities of one of skill to choose, and synthesize if necessary, an appropriate activated PEG derivative with which to prepare a substrate useful in the present invention. See, Abuchowski *et al.* *Cancer Biochem. Biophys.*, **7**: 175-186 (1984); Abuchowski *et al.*, *J. Biol. Chem.*, **252**: 3582-3586 (1977); Jackson *et al.*, *Anal. Biochem.*, **165**: 114-127 (1987); Koide *et al.*, *Biochem Biophys. Res. Commun.*, **111**: 659-667 (1983); treslyate (Nilsson *et al.*, *Methods Enzymol.*, **104**: 56-69 (1984); Delgado *et al.*, *Biotechnol. Appl. Biochem.*, **12**: 119-128 (1990); N-hydroxysuccinimide derived active esters (Buckmann *et al.*, *Makromol. Chem.*, **182**: 1379-1384 (1981); Joppich *et al.*, *Makromol. Chem.*, **180**: 1381-1384 (1979); Abuchowski *et al.*, *Cancer Biochem. Biophys.*, **7**: 175-186 (1984); Katreet *et al.* *Proc. Natl. Acad. Sci. U.S.A.*, **84**: 1487-1491 (1987); Kitamura *et al.*, *Cancer Res.*, **51**: 4310-4315

- (1991); Boccu *et al.*, *Z. Naturforsch.*, **38C**: 94-99 (1983), carbonates (Zalipsky *et al.*, POLY(ETHYLENE GLYCOL) CHEMISTRY: BIOTECHNICAL AND BIOMEDICAL APPLICATIONS, Harris, Ed., Plenum Press, New York, 1992, pp. 347-370; Zalipsky *et al.*, *Biotechnol. Appl. Biochem.*, **15**: 100-114 (1992); Veronese *et al.*, *Appl. Biochem. Biotech.*, **11**: 141-152 (1985)), imidazolyl formates (Beauchamp *et al.*, *Anal. Biochem.*, **131**: 25-33 (1983); Berger *et al.*, *Blood*, **71**: 1641-1647 (1988)), 4-dithiopyridines (Woghiren *et al.*, *Bioconjugate Chem.*, **4**: 314-318 (1993)), isocyanates (Byun *et al.*, *ASAIO Journal*, M649-M-653 (1992)) and epoxides (U.S. Pat. No. 4,806,595, issued to Noishiki *et al.*, (1989). Other linking groups include the urethane linkage between amino groups and activated PEG. See, Veronese, *et al.*, *Appl. Biochem. Biotechnol.*, **11**: 141-152 (1985).

- In another exemplary embodiment in which a reactive PEG derivative is utilized, the invention provides a method for extending the blood-circulation half-life of a selected peptide, in essence targeting the peptide to the blood pool, by conjugating the peptide to a synthetic or natural polymer of a size sufficient to retard the filtration of the protein by the glomerulus (e.g., albumin). This embodiment of the invention is illustrated in Scheme 3 in which erythropoietin (EPO) is conjugated to albumin via a PEG linker using a combination of chemical and enzymatic modification.

Scheme 3



- Thus, as shown in Scheme 3, an amino acid residue of albumin is modified with a reactive PEG derivative, such as X-PEG-(CMP-sialic acid), in which X is an activating group (e.g., active ester, isothiocyanate, etc). The PEG derivative and EPO are combined and contacted with a transferase for which CMP-sialic acid is a substrate. In a further illustrative embodiment, an ϵ -amine of lysine is reacted with the N-hydroxysuccinimide ester of the

PEG-linker to form the albumin conjugate. The CMP-sialic acid of the linker is enzymatically conjugated to an appropriate residue on EPO, e.g., Gal, thereby forming the conjugate. Those of skill will appreciate that the above-described method is not limited to the reaction partners set forth. Moreover, the method can be practiced to form conjugates that include more than two protein moieties by, for example, utilizing a branched linker having more than two termini.

2. Modified Sugars

Modified glycosyl donor species ("modified sugars") are preferably selected from modified sugar nucleotides, activated modified sugars and modified sugars that are simple saccharides that are neither nucleotides nor activated. Any desired carbohydrate structure can be added to a peptide using the methods of the invention. Typically, the structure will be a monosaccharide, but the present invention is not limited to the use of modified monosaccharide sugars; oligosaccharides and polysaccharides are useful as well.

The modifying group is attached to a sugar moiety by enzymatic means, chemical means or a combination thereof, thereby producing a modified sugar. The sugars are substituted at any position that allows for the attachment of the modifying moiety, yet which still allows the sugar to function as a substrate for the enzyme used to ligate the modified sugar to the peptide. In a preferred embodiment, when sialic acid is the sugar, the sialic acid is substituted with the modifying group at either the 9-position on the pyruvyl side chain or at the 5-position on the amine moiety that is normally acetylated in sialic acid.

In certain embodiments of the present invention, a modified sugar nucleotide is utilized to add the modified sugar to the peptide. Exemplary sugar nucleotides that are used in the present invention in their modified form include nucleotide mono-, di- or triphosphates or analogs thereof. In a preferred embodiment, the modified sugar nucleotide is selected from a UDP-glycoside, CMP-glycoside, or a GDP-glycoside. Even more preferably, the modified sugar nucleotide is selected from an UDP-galactose, UDP-galactosamine, UDP-glucose, UDP-glucosamine, GDP-mannose, GDP-fucose, CMP-sialic acid, or CMP-NeuAc. N-acetylamine derivatives of the sugar nucleotides are also of use in the method of the invention.

The invention also provides methods for synthesizing a modified peptide using a modified sugar, *e.g.*, modified-galactose, -fucose, and -sialic acid. When a modified sialic acid is used, either a sialyltransferase or a trans-sialidase (for α 2,3-linked sialic acid only) can be used in these methods.

5 In other embodiments, the modified sugar is an activated sugar. Activated modified sugars, which are useful in the present invention are typically glycosides which have been synthetically altered to include an activated leaving group. As used herein, the term "activated leaving group" refers to those moieties, which are easily displaced in enzyme-regulated nucleophilic substitution reactions. Many activated sugars are known in the art. 10 See, for example, Vocadlo *et al.*, In CARBOHYDRATE CHEMISTRY AND BIOLOGY, Vol. 2, Ernst *et al.* Ed., Wiley-VCH Verlag: Weinheim, Germany, 2000; Kodama *et al.*, *Tetrahedron Lett.* 34: 6419 (1993); Loughheed, *et al.*, *J. Biol. Chem.* 274: 37717 (1999)).

Examples of activating groups (leaving groups) include fluoro, chloro, bromo, tosylate ester, mesylate ester, triflate ester and the like. Preferred activated leaving groups, 15 for use in the present invention, are those that do not significantly sterically encumber the enzymatic transfer of the glycoside to the acceptor. Accordingly, preferred embodiments of activated glycoside derivatives include glycosyl fluorides and glycosyl mesylates, with glycosyl fluorides being particularly preferred. Among the glycosyl fluorides, α -galactosyl fluoride, α -mannosyl fluoride, α -glucosyl fluoride, α -fucosyl fluoride, α -xylosyl fluoride, α -sialyl fluoride, α -N-acetylglucosaminyl fluoride, α -N-acetylgalactosaminyl fluoride, β -galactosyl fluoride, β -mannosyl fluoride, β -glucosyl fluoride, β -fucosyl fluoride, β -xylosyl fluoride, β -sialyl fluoride, β -N-acetylglucosaminyl fluoride and β -N-acetylgalactosaminyl fluoride are most preferred. 20

By way of illustration, glycosyl fluorides can be prepared from the free sugar by first 25 acetylating the sugar and then treating it with HF/pyridine. This generates the thermodynamically most stable anomer of the protected (acetylated) glycosyl fluoride (*i.e.*, the α -glycosyl fluoride). If the less stable anomer (*i.e.*, the β -glycosyl fluoride) is desired, it can be prepared by converting the peracetylated sugar with HBr/HOAc or with HCl to generate the anomeric bromide or chloride. This intermediate is reacted with a fluoride salt 30 such as silver fluoride to generate the glycosyl fluoride. Acetylated glycosyl fluorides may

be deprotected by reaction with mild (catalytic) base in methanol (e.g. NaOMe/MeOH). In addition, many glycosyl fluorides are commercially available.

Other activated glycosyl derivatives can be prepared using conventional methods known to those of skill in the art. For example, glycosyl mesylates can be prepared by treatment of the fully benzylated hemiacetal form of the sugar with mesyl chloride, followed by catalytic hydrogenation to remove the benzyl groups.

In a further exemplary embodiment, the modified sugar is an oligosaccharide having an antennary structure. In a preferred embodiment, one or more of the termini of the antennae bear the modifying moiety. When more than one modifying moiety is attached to an oligosaccharide having an antennary structure, the oligosaccharide is useful to "amplify" the modifying moiety; each oligosaccharide unit conjugated to the peptide attaches multiple copies of the modifying group to the peptide. The general structure of a typical chelate of the invention as set forth in the drawing above, encompasses multivalent species resulting from preparing a conjugate of the invention utilizing an antennary structure. Many antennary saccharide structures are known in the art, and the present method can be practiced with them without limitation.

Exemplary modifying groups are discussed below. The modifying groups can be selected for one or more desirable property. Exemplary properties include, but are not limited to, enhanced pharmacokinetics, enhanced pharmacodynamics, improved biodistribution, providing a polyvalent species, improved water solubility, enhanced or diminished lipophilicity, and tissue targeting.

D. Peptide Conjugates

a) Water-Soluble Polymers

The hydrophilicity of a selected peptide is enhanced by conjugation with polar molecules such as amine-, ester-, hydroxyl- and polyhydroxyl-containing molecules. Representative examples include, but are not limited to, polylysine, polyethylenimine, poly(ethylene glycol) and poly(propyleneglycol). Preferred water-soluble polymers are essentially non-fluorescent, or emit such a minimal amount of fluorescence that they are inappropriate for use as a fluorescent marker in an assay. Polymers that are not naturally occurring sugars may be used. In addition, the use of an otherwise naturally occurring sugar that is modified by covalent attachment of another entity (e.g., poly(ethylene glycol)),

poly(propylene glycol), poly(aspartate), biomolecule, therapeutic moiety, diagnostic moiety, *etc.*) is also contemplated. In another exemplary embodiment, a therapeutic sugar moiety is conjugated to a linker arm and the sugar-linker arm is subsequently conjugated to a peptide via a method of the invention.

- 5 Methods and chemistry for activation of water-soluble polymers and saccharides as well as methods for conjugating saccharides and polymers to various species are described in the literature. Commonly used methods for activation of polymers include activation of functional groups with cyanogen bromide, periodate, glutaraldehyde, biepoxydes, epichlorohydrin, divinylsulfone, carbodiimide, sulfonyl halides, trichlorotriazine, *etc.* (*see*, R. F. Taylor, (1991), PROTEIN IMMOBILISATION. FUNDAMENTALS AND APPLICATIONS, Marcel Dekker, N.Y.; S. S. Wong, (1992), CHEMISTRY OF PROTEIN CONJUGATION AND CROSSLINKING, CRC Press, Boca Raton; G. T. Hermanson *et al.*, (1993), IMMOBILIZED AFFINITY LIGAND TECHNIQUES, Academic Press, N.Y.; Dunn, R.L., *et al.*, Eds. POLYMERIC DRUGS AND DRUG DELIVERY SYSTEMS, ACS Symposium Series Vol. 469, American Chemical Society, Washington, D.C. 1991).
- 10 Routes for preparing reactive PEG molecules and forming conjugates using the reactive molecules are known in the art. For example, U.S. Patent No. 5,672,662 discloses a water soluble and isolatable conjugate of an active ester of a polymer acid selected from linear or branched poly(alkylene oxides), poly(oxyethylated polyols), poly(olefinic alcohols), and poly(acrylomorpholine), wherein the polymer has about 44 or more recurring units.
- 15 U.S. Patent No. 6,376,604 sets forth a method for preparing a water-soluble 1-benzotriazolylcarbonate ester of a water-soluble and non-peptidic polymer by reacting a terminal hydroxyl of the polymer with di(1-benzotriazolyl)carbonate in an organic solvent. The active ester is used to form conjugates with a biologically active agent such as a protein or peptide.
- 20 WO 99/45964 describes a conjugate comprising a biologically active agent and an activated water soluble polymer comprising a polymer backbone having at least one terminus linked to the polymer backbone through a stable linkage, wherein at least one terminus comprises a branching moiety having proximal reactive groups linked to the branching moiety, in which the biologically active agent is linked to at least one of the proximal reactive groups. Other branched poly(ethylene glycols) are described in WO 96/21469, U.S. Patent

No. 5,932,462 describes a conjugate formed with a branched PEG molecule that includes a branched terminus that includes reactive functional groups. The free reactive groups are available to react with a biologically active species, such as a protein or peptide, forming conjugates between the poly(ethylene glycol) and the biologically active species. U.S. Patent No. 5,446,090 describes a bifunctional PEG linker and its use in forming conjugates having a peptide at each of the PEG linker termini.

Conjugates that include degradable PEG linkages are described in WO 99/34833; and WO 99/14259, as well as in U.S. Patent No. 6,348,558. Such degradable linkages are applicable in the present invention.

Although both reactive PEG derivatives and conjugates formed using the derivatives are known in the art, until the present invention, it was not recognized that a conjugate could be formed between PEG (or other polymer) and another species, such as a peptide or glycopeptide, through an intact glycosyl linking group.

Many water-soluble polymers are known to those of skill in the art and are useful in practicing the present invention. The term water-soluble polymer encompasses species such as saccharides (e.g., dextran, amylose, hyaluronic acid, poly(sialic acid), heparans, heparins, etc.); poly (amino acids), e.g., poly(glutamic acid); nucleic acids; synthetic polymers (e.g., poly(acrylic acid), poly(ethers), e.g., poly(ethylene glycol); peptides, proteins, and the like. The present invention may be practiced with any water-soluble polymer with the sole limitation that the polymer must include a point at which the remainder of the conjugate can be attached.

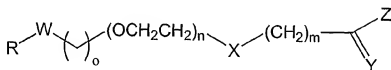
Methods for activation of polymers can also be found in WO 94/17039, U.S. Pat. No. 5,324,844, WO 94/18247, WO 94/04193, U.S. Pat. No. 5,219,564, U.S. Pat. No. 5,122,614, WO 90/13540, U.S. Pat. No. 5,281,698, and more WO 93/15189, and for conjugation between activated polymers and peptides, e.g. Coagulation Factor VIII (WO 94/15625), hemoglobin (WO 94/09027), oxygen carrying molecule (U.S. Pat. No. 4,412,989), ribonuclease and superoxide dismutase (Veronese *et al.*, *App. Biochem. Biotech.* 11: 141-45 (1985)).

Preferred water-soluble polymers are those in which a substantial proportion of the polymer molecules in a sample of the polymer are of approximately the same molecular weight; such polymers are "homodisperse."

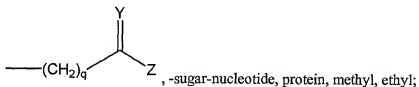
The present invention is further illustrated by reference to a poly(ethylene glycol) conjugate. Several reviews and monographs on the functionalization and conjugation of PEG are available. See, for example, Harris, *Macromol. Chem. Phys.* **C25**: 325-373 (1985); Scouten, *Methods in Enzymology* **135**: 30-65 (1987); Wong *et al.*, *Enzyme Microb. Technol.* **14**: 866-874 (1992); Delgado *et al.*, *Critical Reviews in Therapeutic Drug Carrier Systems* **9**: 249-304 (1992); Zalipsky, *Bioconjugate Chem.* **6**: 150-165 (1995); and Bhadra, *et al.*, *Pharmazie*, **57**:5-29 (2002).

Poly(ethylene glycol) molecules suitable for use in the invention include, but are not limited to, those described by the following Formula 3:

10

Formula 3.

R = H, alkyl, benzyl, aryl, acetal, OHC-, H₂N-CH₂CH₂-, HS-CH₂CH₂-,



15 X, Y, W, U (independently selected) = O, S, NH, N-R';

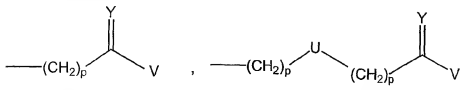
R', R''' (independently selected) = alkyl, benzyl, aryl, alkyl aryl, pyridyl, substituted aryl, arylalkyl, acylaryl;

n = 1 to 2000;

m, q, p (independently selected) = 0 to 20

20 o = 0 to 20;

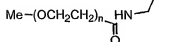
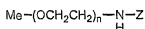
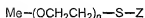
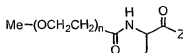
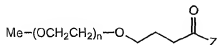
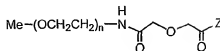
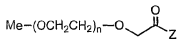
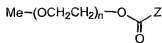
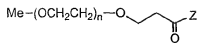
Z = HO, NH₂, halogen, S-R'', activated esters,



---sugar-nucleotide, protein, imidazole, HOBT, tetrazole, halide; and

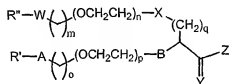
V = HO, NH₂, halogen, S-R''', activated esters, activated amides, ---sugar-nucleotide, protein.

In preferred embodiments, the poly(ethylene glycol) molecule is selected from the following:



The poly(ethylene glycol) useful in forming the conjugate of the invention is either linear or branched. Branched poly(ethylene glycol) molecules suitable for use in the invention include, but are not limited to, those described by the following Formula:

Formula 4:



5

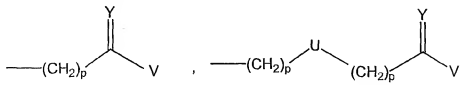
R', R'', R''' (independently selected) = H, alkyl, benzyl, aryl, acetal, OHC-, H₂N-CH₂CH₂-, HS-CH₂CH₂-, -(CH₂)_qCY-Z, -sugar-nucleotide, protein, methyl, ethyl, heteroaryl, acylalkyl, acylaryl, acylalkylaryl;

X, Y, W, A, B (independently selected) = O, S, NH, N-R', (CH₂)_i;

10 n, p (independently selected) = 1 to 2000;

m, q, o (independently selected) = 0 to 20;

Z = HO, NH₂, halogen, S-R''', activated esters,



-sugar-nucleotide, protein;

15 V = HO, NH₂, halogen, S-R''', activated esters, activated amides,

-sugar-nucleotide, protein.

The *in vivo* half-life, area under the curve, and/or residence time of therapeutic peptides can also be enhanced with water-soluble polymers such as polyethylene glycol (PEG) and polypropylene glycol (PPG). For example, chemical modification of proteins with PEG (PEGylation) increases their molecular size and decreases their surface- and functional group-accessibility, each of which are dependent on the size of the PEG attached to the protein. This results in an improvement of plasma half-lives and in proteolytic-stability, and a decrease in immunogenicity and hepatic uptake (Chaffee *et al. J. Clin. Invest.* 89: 1643-1651 (1992); Pyatak *et al. Res. Commun. Chem. Pathol Pharmacol.* 29: 113-127 (1980)). PEGylation of interleukin-2 has been reported to increase its antitumor potency *in vivo* (Katre *et al. Proc. Natl. Acad. Sci. USA.* 84: 1487-1491 (1987)) and PEGylation of a F(ab')₂ derived from the monoclonal antibody A7 has improved its tumor localization (Kitamura *et al. Biochem. Biophys. Res. Commun.* 28: 1387-1394 (1990)).

In one preferred embodiment, the *in vivo* half-life of a peptide derivatized with a water-soluble polymer by a method of the invention is increased relevant to the *in vivo* half-life of the non-derivatized peptide. In another preferred embodiment, the area under the curve of a peptide derivatized with a water-soluble polymer using a method of the invention is increased relevant to the area under the curve of the non-derivatized peptide. In another preferred embodiment, the residence time of a peptide derivatized with a water-soluble polymer using a method of the invention is increased relevant to the residence time of the non-derivatized peptide. Techniques to determine the *in vivo* half-life, the area under the curve and the residence time are well known in the art. Descriptions of such techniques can be found in J.G. Wagner, 1993, *Pharmacokinetics for the Pharmaceutical Scientist*, Technomic Publishing Company, Inc. Lancaster PA.

The increase in peptide *in vivo* half-life is best expressed as a range of percent increase in this quantity. The lower end of the range of percent increase is about 40%, about 60%, about 80%, about 100%, about 150% or about 200%. The upper end of the range is about 60%, about 80%, about 100%, about 150%, or more than about 250%.

In an exemplary embodiment, the present invention provides a PEGylated follicle stimulating hormone (Examples 23 and 24). In a further exemplary embodiment, the invention provides a PEGylated transferrin (Example 42).

Other exemplary water-soluble polymers of use in the invention include, but are not limited to linear or branched poly(alkylene oxides), poly(oxyethylated polyols), poly(olefinic alcohols), and poly(acrylomorpholine), dextran, starch, poly(amino acids), etc.

b) Water-insoluble polymers

5 The conjugates of the invention may also include one or more water-insoluble polymers. This embodiment of the invention is illustrated by the use of the conjugate as a vehicle with which to deliver a therapeutic peptide in a controlled manner. Polymeric drug delivery systems are known in the art. See, for example, Dunn *et al.*, Eds. POLYMERIC DRUGS AND DRUG DELIVERY SYSTEMS, ACS Symposium Series Vol. 469, American Chemical Society, Washington, D.C. 1991. Those of skill in the art will appreciate that substantially any known drug delivery system is applicable to the conjugates of the present invention.

Representative water-insoluble polymers include, but are not limited to, polyphosphazines, poly(vinyl alcohols), polyamides, polycarbonates, polyalkylenes, 15 polyacrylamides, polyalkylene glycols, polyalkylene oxides, polyalkylene terephthalates, polyvinyl ethers, polyvinyl esters, polyvinyl halides, polyvinylpyrrolidone, polyglycolides, polysiloxanes, polyurethanes, poly(methyl methacrylate), poly(ethyl methacrylate), poly(butyl methacrylate), poly(isobutyl methacrylate), poly(hexyl methacrylate), poly(isodecyl methacrylate), poly(lauryl methacrylate), poly(phenyl methacrylate), 20 poly(methyl acrylate), poly(isopropyl acrylate), poly(isobutyl acrylate), poly(octadecyl acrylate) polyethylene, polypropylene, poly(ethylene glycol), poly(ethylene oxide), poly(ethylene terephthalate), poly(vinyl acetate), polyvinyl chloride, polystyrene, polyvinyl pyrrolidone, pluronics and polyvinylphenol and copolymers thereof.

Synthetically modified natural polymers of use in conjugates of the invention include, 25 but are not limited to, alkyl celluloses, hydroxyalkyl celluloses, cellulose ethers, cellulose esters, and nitrocelluloses. Particularly preferred members of the broad classes of synthetically modified natural polymers include, but are not limited to, methyl cellulose, ethyl cellulose, hydroxypropyl cellulose, hydroxypropyl methyl cellulose, hydroxybutyl methyl cellulose, cellulose acetate, cellulose propionate, cellulose acetate butyrate, cellulose acetate phthalate, carboxymethyl cellulose, cellulose triacetate, cellulose sulfate sodium salt, 30 and polymers of acrylic and methacrylic esters and alginic acid.

These and the other polymers discussed herein can be readily obtained from commercial sources such as Sigma Chemical Co. (St. Louis, MO.), Polysciences (Warrenton, PA.), Aldrich (Milwaukee, WI.), Fluka (Ronkonkoma, NY), and BioRad (Richmond, CA), or else synthesized from monomers obtained from these suppliers using standard techniques.

Representative biodegradable polymers of use in the conjugates of the invention include, but are not limited to, polylactides, polyglycolides and copolymers thereof, poly(ethylene terephthalate), poly(butyric acid), poly(valeric acid), poly(lactide-co-caprolactone), poly(lactide-co-glycolide), polyanhydrides, polyorthoesters, blends and copolymers thereof. Of particular use are compositions that form gels, such as those including collagen, pluronics and the like.

The polymers of use in the invention include "hybrid" polymers that include water-insoluble materials having within at least a portion of their structure, a bioresorbable molecule. An example of such a polymer is one that includes a water-insoluble copolymer, which has a bioresorbable region, a hydrophilic region and a plurality of crosslinkable functional groups per polymer chain.

For purposes of the present invention, "water-insoluble materials" includes materials that are substantially insoluble in water or water-containing environments. Thus, although certain regions or segments of the copolymer may be hydrophilic or even water-soluble, the polymer molecule, as a whole, does not to any substantial measure dissolve in water.

For purposes of the present invention, the term "bioresorbable molecule" includes a region that is capable of being metabolized or broken down and resorbed and/or eliminated through normal excretory routes by the body. Such metabolites or break down products are preferably substantially non-toxic to the body.

The bioresorbable region may be either hydrophobic or hydrophilic, so long as the copolymer composition as a whole is not rendered water-soluble. Thus, the bioresorbable region is selected based on the preference that the polymer, as a whole, remains water-insoluble. Accordingly, the relative properties, *i.e.*, the kinds of functional groups contained by, and the relative proportions of the bioresorbable region, and the hydrophilic region are selected to ensure that useful bioresorbable compositions remain water-insoluble.

Exemplary resorbable polymers include, for example, synthetically produced resorbable block copolymers of poly(α -hydroxy-carboxylic acid)/poly(oxyalkylene), (*see*,

Cohn *et al.*, U.S. Patent No. 4,826,945). These copolymers are not crosslinked and are water-soluble so that the body can excrete the degraded block copolymer compositions. *See*, Younes *et al.*, *J Biomed. Mater. Res.* **21**: 1301-1316 (1987); and Cohn *et al.*, *J Biomed. Mater. Res.* **22**: 993-1009 (1988).

5 Presently preferred bioresorbable polymers include one or more components selected from poly(esters), poly(hydroxy acids), poly(lactones), poly(amides), poly(ester-amides), poly(amino acids), poly(anhydrides), poly(orthoesters), poly(carbonates), poly(phosphazines), poly(phosphoesters), poly(thioesters), polysaccharides and mixtures thereof. More preferably still, the bioresorbable polymer includes a poly(hydroxy) acid
10 component. Of the poly(hydroxy) acids, polylactic acid, polyglycolic acid, polycaproic acid, polybutyric acid, polyvaleric acid and copolymers and mixtures thereof are preferred.

In addition to forming fragments that are absorbed *in vivo* ("bioresorbed"), preferred polymeric coatings for use in the methods of the invention can also form an excretable and/or metabolizable fragment.

15 Higher order copolymers can also be used in the present invention. For example, Casey *et al.*, U.S. Patent No. 4,438,253, which issued on March 20, 1984, discloses tri-block copolymers produced from the transesterification of poly(glycolic acid) and an hydroxyl-ended poly(alkylene glycol). Such compositions are disclosed for use as resorbable monofilament sutures. The flexibility of such compositions is controlled by the incorporation
20 of an aromatic orthocarbonate, such as tetra-p-tolyl orthocarbonate into the copolymer structure.

Other coatings based on lactic and/or glycolic acids can also be utilized. For example, Spinu, U.S. Patent No. 5,202,413, which issued on April 13, 1993, discloses biodegradable multi-block copolymers having sequentially ordered blocks of polylactide and/or
25 polyglycolide produced by ring-opening polymerization of lactide and/or glycolide onto either an oligomeric diol or a diamine residue followed by chain extension with a difunctional compound, such as, a diisocyanate, diacylchloride or dichlorosilane.

Bioresorbable regions of coatings useful in the present invention can be designed to be hydrolytically and/or enzymatically cleavable. For purposes of the present invention,
30 "hydrolytically cleavable" refers to the susceptibility of the copolymer, especially the bioresorbable region, to hydrolysis in water or a water-containing environment. Similarly,

"enzymatically cleavable" as used herein refers to the susceptibility of the copolymer, especially the bioresorbable region, to cleavage by endogenous or exogenous enzymes.

When placed within the body, the hydrophilic region can be processed into excretable and/or metabolizable fragments. Thus, the hydrophilic region can include, for example, polyethers, polyalkylene oxides, polyols, poly(vinyl pyrrolidine), poly(vinyl alcohol), poly(alkyl oxazolines), polysaccharides, carbohydrates, peptides, proteins and copolymers and mixtures thereof. Furthermore, the hydrophilic region can also be, for example, a poly(alkylene) oxide. Such poly(alkylene) oxides can include, for example, poly(ethylene) oxide, poly(propylene) oxide and mixtures and copolymers thereof.

Polymers that are components of hydrogels are also useful in the present invention. Hydrogels are polymeric materials that are capable of absorbing relatively large quantities of water. Examples of hydrogel forming compounds include, but are not limited to, polyacrylic acids, sodium carboxymethylcellulose, polyvinyl alcohol, polyvinyl pyrrolidine, gelatin, carrageenan and other polysaccharides, hydroxyethylenemethacrylic acid (HEMA), as well as derivatives thereof, and the like. Hydrogels can be produced that are stable, biodegradable and bioresorbable. Moreover, hydrogel compositions can include subunits that exhibit one or more of these properties.

Bio-compatible hydrogel compositions whose integrity can be controlled through crosslinking are known and are presently preferred for use in the methods of the invention. For example, Hubbell *et al.*, U.S. Patent Nos. 5,410,016, which issued on April 25, 1995 and 5,529,914, which issued on June 25, 1996, disclose water-soluble systems, which are crosslinked block copolymers having a water-soluble central block segment sandwiched between two hydrolytically labile extensions. Such copolymers are further end-capped with photopolymerizable acrylate functionalities. When crosslinked, these systems become hydrogels. The water soluble central block of such copolymers can include poly(ethylene glycol); whereas, the hydrolytically labile extensions can be a poly(α -hydroxy acid), such as polyglycolic acid or polylactic acid. See, Sawhney *et al.*, *Macromolecules* 26: 581-587 (1993).

In another preferred embodiment, the gel is a thermoreversible gel. Thermoreversible gels including components, such as pluronics, collagen, gelatin, hyaluronic acid,

polysaccharides, polyurethane hydrogel, polyurethane-urea hydrogel and combinations thereof are presently preferred.

In yet another exemplary embodiment, the conjugate of the invention includes a component of a liposome. Liposomes can be prepared according to methods known to those skilled in the art, for example, as described in Epstein *et al.*, U.S. Patent No. 4,522,811, which issued on June 11, 1985. For example, liposome formulations may be prepared by dissolving appropriate lipid(s) (such as stearyl phosphatidyl ethanolamine, stearyl phosphatidyl choline, arachadyl phosphatidyl choline, and cholesterol) in an inorganic solvent that is then evaporated, leaving behind a thin film of dried lipid on the surface of the container. An aqueous solution of the active compound or its pharmaceutically acceptable salt is then introduced into the container. The container is then swirled by hand to free lipid material from the sides of the container and to disperse lipid aggregates, thereby forming the liposomal suspension.

The above-recited microparticles and methods of preparing the microparticles are offered by way of example and they are not intended to define the scope of microparticles of use in the present invention. It will be apparent to those of skill in the art that an array of microparticles, fabricated by different methods, are of use in the present invention.

c) Biomolecules

In another preferred embodiment, the modified sugar bears a biomolecule. In still further preferred embodiments, the biomolecule is a functional protein, enzyme, antigen, antibody, peptide, nucleic acid (*e.g.*, single nucleotides or nucleosides, oligonucleotides, polynucleotides and single- and higher-stranded nucleic acids), lectin, receptor or a combination thereof.

Some preferred biomolecules are essentially non-fluorescent, or emit such a minimal amount of fluorescence that they are inappropriate for use as a fluorescent marker in an assay. Other biomolecules may be fluorescent. The use of an otherwise naturally occurring sugar that is modified by covalent attachment of another entity (*e.g.*, PEG, biomolecule, therapeutic moiety, diagnostic moiety, *etc.*) is appropriate. In an exemplary embodiment, a sugar moiety, which is a biomolecule, is conjugated to a linker arm and the sugar-linker arm cassette is subsequently conjugated to a peptide via a method of the invention.

Biomolecules useful in practicing the present invention can be derived from any source. The biomolecules can be isolated from natural sources or they can be produced by synthetic methods. Peptides can be natural peptides or mutated peptides. Mutations can be effected by chemical mutagenesis, site-directed mutagenesis or other means of inducing mutations known to those of skill in the art. Peptides useful in practicing the instant invention include, for example, enzymes, antigens, antibodies and receptors. Antibodies can be either polyclonal or monoclonal; either intact or fragments. The peptides are optionally the products of a program of directed evolution.

Both naturally derived and synthetic peptides and nucleic acids are of use in conjunction with the present invention; these molecules can be attached to a sugar residue component or a crosslinking agent by any available reactive group. For example, peptides can be attached through a reactive amine, carboxyl, sulfhydryl, or hydroxyl group. The reactive group can reside at a peptide terminus or at a site internal to the peptide chain. Nucleic acids can be attached through a reactive group on a base (e.g., exocyclic amine) or an available hydroxyl group on a sugar moiety (e.g., 3'- or 5'-hydroxyl). The peptide and nucleic acid chains can be further derivatized at one or more sites to allow for the attachment of appropriate reactive groups onto the chain. See, Chrisey *et al. Nucleic Acids Res.* **24**: 3031-3039 (1996).

In a further preferred embodiment, the biomolecule is selected to direct the peptide modified by the methods of the invention to a specific tissue, thereby enhancing the delivery of the peptide to that tissue relative to the amount of underivatized peptide that is delivered to the tissue. In a still further preferred embodiment, the amount of derivatized peptide delivered to a specific tissue within a selected time period is enhanced by derivatization by at least about 20%, more preferably, at least about 40%, and more preferably still, at least about 100%. Presently, preferred biomolecules for targeting applications include antibodies, hormones and ligands for cell-surface receptors. Exemplary targeting biomolecules include, but are not limited to, an antibody specific for the transferrin receptor for delivery of the molecule to the brain (Penichet *et al.*, 1999, *J. Immunol.* 163:4421-4426; Pardridge, 2002, *Adv. Exp. Med. Biol.* 513:397-430), a peptide that recognizes the vasculature of the prostate (Arap *et al.*, 2002, *PNAS* 99:1527-1531), and an antibody specific for lung caveolae (McIntosh *et al.*, 2002, *PNAS* 99:1996-2001).

In a presently preferred embodiment, the modifying group is a protein. In an exemplary embodiment, the protein is an interferon. The interferons are antiviral glycoproteins that, in humans, are secreted by human primary fibroblasts after induction with virus or double-stranded RNA. Interferons are of interest as therapeutics, e.g., antivirals and treatment of multiple sclerosis. For references discussing interferon- β , see, e.g., Yu, *et al.*, *J. Neuroimmunol.*, **64**(1):91-100 (1996); Schmidt, J., *J. Neurosci. Res.*, **65**(1):59-67 (2001); Wender, *et al.*, *Folia Neuropathol.*, **39**(2):91-93 (2001); Martin, *et al.*, *Springer Semin. Immunopathol.*, **18**(1):1-24 (1996); Takane, *et al.*, *J. Pharmacol. Exp. Ther.*, **294**(2):746-752 (2000); Sburlati, *et al.*, *Biotechnol. Prog.*, **14**:189-192 (1998); Dodd, *et al.*, *Biochimica et Biophysica Acta*, **787**:183-187 (1984); Edelbaum, *et al.*, *J. Interferon Res.*, **12**:449-453 (1992); Conradt, *et al.*, *J. Biol. Chem.*, **262**(30):14600-14605 (1987); Civas, *et al.*, *Eur. J. Biochem.*, **173**:311-316 (1988); Demolder, *et al.*, *J. Biotechnol.*, **32**:179-189 (1994); Sedmak, *et al.*, *J. Interferon Res.*, **9**(Suppl 1):S61-S65 (1989); Kagawa, *et al.*, *J. Biol. Chem.*, **263**(33):17508-17515 (1988); Hershenson, *et al.*, U.S. Patent No. 4,894,330; Jayaram, *et al.*, *J. Interferon Res.*, **3**(2):177-180 (1983); Menge, *et al.*, *Develop. Biol. Standard.*, **66**:391-401 (1987); Vonk, *et al.*, *J. Interferon Res.*, **3**(2):169-175 (1983); and Adolf, *et al.*, *J. Interferon Res.*, **10**:255-267 (1990). For references relevant to interferon- α , see, Asano, *et al.*, *Eur. J. Cancer*, **27**(Suppl 4):S21-S25 (1991); Nagy, *et al.*, *Anticancer Research*, **8**(3):467-470 (1988); Dron, *et al.*, *J. Biol. Regul. Homeost. Agents*, **3**(1):13-19 (1989); Habib, *et al.*, *Am. Surg.*, **67**(3):257-260 (3/2001); and Sugiyama, *et al.*, *Eur. J. Biochem.*, **217**:921-927 (1993).

In an exemplary interferon conjugate, interferon β is conjugated to a second peptide via a linker arm. The linker arm includes an intact glycosyl linking group through which it is attached to the second peptide via a method of the invention. The linker arm also optionally includes a second intact glycosyl linking group, through which it is attached to the interferon.

In another exemplary embodiment, the invention provides a conjugate of follicle stimulating hormone (FSH). FSH is a glycoprotein hormone. See, for example, Saneyoshi, *et al.*, *Biol. Reprod.*, **65**:1686-1690 (2001); Hakola, *et al.*, *J. Endocrinol.*, **158**:441-448 (1998); Stanton, *et al.*, *Mol. Cell. Endocrinol.*, **125**:133-141 (1996); Walton, *et al.*, *J. Clin. Endocrinol. Metab.*, **86**(8):3675-3685 (08/2001); Ulloa-Aguirre, *et al.*, *Endocrine*, **11**(3):205-215 (12/1999); Castro-Fernández, *et al.*, *J. Clin. Endocrinol. Metab.*, **85**(12):4603-4610 (2000); Prevost, Rebecca R., *Pharmacotherapy*, **18**(5):1001-1010 (1998); Linskens, *et al.*,

The FASEB Journal, **13**:639-645 (04/1999); Butnev, *et al.*, *Biol. Reprod.*, **58**:458-469 (1998); Muyan, *et al.*, *Mol. Endo.*, **12**(5):766-772 (1998); Min, *et al.*, *Endo. J.*, **43**(5):585-593 (1996); Boime, *et al.*, *Recent Progress in Hormone Research*, **34**:271-289 (1999); and Rafferty, *et al.*, *J. Endo.*, **145**:527-533 (1995). The FSH conjugate can be formed in a manner similar to that described for interferon.

In yet another exemplary embodiment, the conjugate includes erythropoietin (EPO). EPO is known to mediate response to hypoxia and to stimulate the production of red blood cells. For pertinent references, *see*, Cerami, *et al.*, *Seminars in Oncology*, **28**(2)(Suppl 8):66-70 (04/2001). An exemplary EPO conjugate is formed analogously to the conjugate of interferon.

In a further exemplary embodiment, the invention provides a conjugate of human granulocyte colony stimulating factor (G-CSF). G-CSF is a glycoprotein that stimulates proliferation, differentiation and activation of neutropoietic progenitor cells into functionally mature neutrophils. Injected G-CSF is known to be rapidly cleared from the body. *See*, for example, Nohynek, *et al.*, *Cancer Chemother. Pharmacol.*, **39**:259-266 (1997); Lord, *et al.*, *Clinical Cancer Research*, **7**(7):2085-2090 (07/2001); Rotondaro, *et al.*, *Molecular Biotechnology*, **11**(2):117-128 (1999); and Bönig, *et al.*, *Bone Marrow Transplantation*, **28**:259-264 (2001). An exemplary conjugate of G-CSF is prepared as discussed above for the conjugate of the interferons. One of skill in the art will appreciate that many other proteins may be conjugated to interferon using the methods and compositions of the invention, including but not limited to, the peptides listed in Tables 7 and 8 (presented elsewhere herein) and Figure 28, and in Figures 29-57, where individual modification schemes are presented.

In still a further exemplary embodiment, there is provided a conjugate with biotin. Thus, for example, a selectively biotinylated peptide is elaborated by the attachment of an avidin or streptavidin moiety bearing one or more modifying groups.

In a further preferred embodiment, the biomolecule is selected to direct the peptide modified by the methods of the invention to a specific intracellular compartment, thereby enhancing the delivery of the peptide to that intracellular compartment relative to the amount of underivatized peptide that is delivered to the tissue. In a still further preferred embodiment, the amount of derivatized peptide delivered to a specific intracellular

compartment within a selected time period is enhanced by derivatization by at least about 20%, more preferably, at least about 40%, and more preferably still, at least about 100%. In another particularly preferred embodiment, the biomolecule is linked to the peptide by a cleavable linker that can hydrolyze once internalized. Presently, preferred biomolecules for intracellular targeting applications include transferrin, lactotransferrin (lactoferrin), melanotransferrin (p97), ceruloplasmin, and divalent cation transporter, as well as antibodies directed against specific vascular targets. Contemplated linkages include, but are not limited to, protein-sugar-linker-sugar-protein, protein-sugar-linker-protein and multivalent forms thereof, and protein-sugar-linker-drug where the drug includes small molecules, peptides, lipids, among others.

Site-specific and target-oriented delivery of therapeutic agents is desirable for the purpose of treating a wide variety of human diseases, such as different types of malignancies and certain neurological disorders. Such procedures are accompanied by fewer side effects and a higher efficacy of drug. Various principles have been relied on in designing these delivery systems. For a review, see Garnett, *Advanced Drug Delivery Reviews* 53:171-216 (2001).

One important consideration in designing a drug delivery system to target tissues specifically. The discovery of tumor surface antigens has made it possible to develop therapeutic approaches where tumor cells displaying definable surface antigens are specifically targeted and killed. There are three main classes of therapeutic monoclonal antibodies (antibody) that have demonstrated effectiveness in human clinical trials in treating malignancies: (1) unconjugated MAb, which either directly induces growth inhibition and/or apoptosis, or indirectly activates host defense mechanisms to mediate antitumor cytotoxicity; (2) drug-conjugated MAb, which preferentially delivers a potent cytotoxic toxin to the tumor cells and therefore minimizes the systemic cytotoxicity commonly associated with conventional chemotherapy; and (3) radioisotope-conjugated MAb, which delivers a sterilizing dose of radiation to the tumor. See review by Reff et al., *Cancer Control* 9:152-166 (2002).

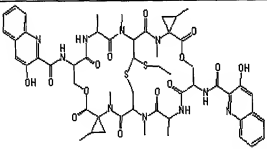
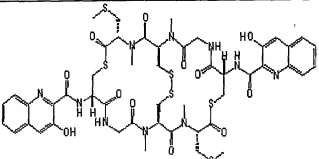
In order to arm MAbs with the power to kill malignant cells, the MAbs can be connected to a toxin, which may be obtained from a plant, bacterial, or fungal source, to form chimeric proteins called immunotoxins. Frequently used plant toxins are divided into two

classes: (1) holotoxins (or class II ribosome inactivating proteins), such as ricin, abrin, mistletoe lectin, and modeccin, and (2) hemitoxins (class I ribosome inactivating proteins), such as pokeweed antiviral protein (PAP), saporin, Bryodin 1, bouganin, and gelonin.

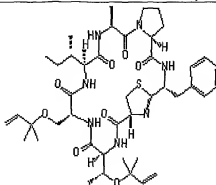
Commonly used bacterial toxins include diphtheria toxin (DT) and *Pseudomonas* exotoxin

- 5 (PE). Kreitman, *Current Pharmaceutical Biotechnology* 2:313-325 (2001). Other toxins contemplated for use with the present invention include, but are not limited to, those in Table 2.

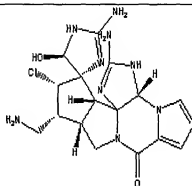
Table 2. Toxins.

Chemical Structure				
Toxin Name/ Source/ Alternate ID	CAS RN / Analog	Indication/ Toxicity	Mechanism	Activity (IC50 nM); Tumor Type
				
SW-163E/ <i>Streptomyces</i> sp SNA 15896/ SW-163E	260794-24-9; 260794-25-0/ SW-163C; SW-163A; SW-163B	Cancer and Antibacterial/ low toxicity (mice ip)	not reported	0.3 P388 0.2 A2780 0.4 KB 1.6 colon 1.3 HL-60
				
Thiocoraline/ <i>Micromonospora marina</i> (actinomycete)	173046-02-1	Breast Cancer; Melanoma; Non-small lung cancer / not reported	DNA Polymerase alpha inhibitor (blocks cell progression from G1 to	lung, colon, CNS melanoma

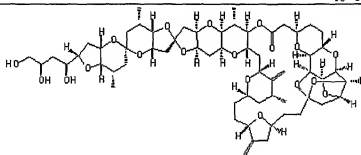
S)



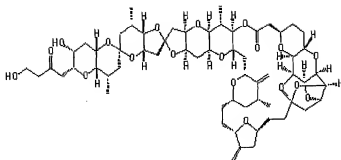
Trunkamide A¹ <i>Lissoctinum</i> sp (aascidian)	181758-83-8	Cancer/ not reported	not reported	cell culture (IC ₅₀ in micrograms/mL); 0.5 P388; 0.5 A549; 0.5 HT-29; 1.0 MEL-28
--	-------------	-------------------------	--------------	--



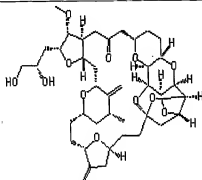
Palauamine² <i>Stylotella agminata</i> (sponge)	148717-58-2	Lung cancer/ LD ₅₀ (i.p. in mice) is 13 mg/Kg	not reported	cell culture (IC ₅₀ in micrograms/mL); 0.1 P388 0.2 A549 (lung) 2 HT-29 (colon) 10 KB
---	-------------	--	--------------	---



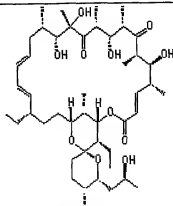
Halichondrin B <i>Halichondria Okada</i> , <i>Axinell Carteri</i> and <i>Phanikell carteri</i> (sponges)/ NSC-609385	103614-76-2/ isohomohalic hondrin B	cancer/ myelotoxicity dose limiting (dogs, rats)	antitubulin; cell cycle inhibitor (inhibits GTP binding to tubulin)	NCI tumor panel; GI(50) from 50 nM to 0.1 nM; LC50's from 40 μM to 0.1 nM (many 0.1 to 25 nM)
--	---	--	--	--



Isohomohalichondrin B / 157078-48-3/ <i>Halichondria Okadai</i> , <i>Axinell Carteri</i> and <i>Phanikell carteri</i> (sponges)/ NSC-650467	halichondrin B	melanoma, lung, CNS, colon, ovary/ not reported	antitubulin; cell cycle inhibitor (inhibits GTP binding to tubulin)	IC50's in 0.1 nM range (NCI tumor panel)
---	-------------------	---	--	---



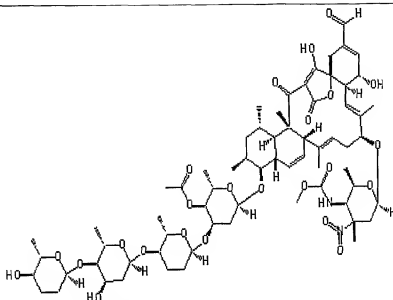
Halichondrin B analogs / semi-synthetic starting from <i>Halichondria</i> <i>Okadai</i> , <i>Axinell Carteri</i> and <i>Phanikell carteri</i> (sponges)/ ER-076349; ER-086526; B-1793; E-7389	253128-15-3/ ER-076349; ER-086526; B-1793; E-7389	solid tumors/ not reported	tubulin binding agent; disruption of mitotic spindles	cell culture (not reported); animal models active (tumor regression observed) in lymphoma, colon (multi-drug resistant).
--	---	-------------------------------	--	--



NK-130119 / <i>Streptomyces</i>	132707-68-7	antifungal and anticancer/	not reported	25 ng/mL colon 8.5 ng/mL lung
---	-------------	-------------------------------	--------------	----------------------------------

bottropensis/
NK-130119

not reported



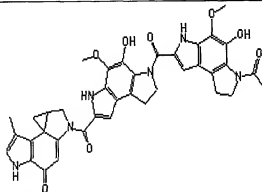
Tetrocarcin A /
not reported/
KF-67544

73666-84-9/
analogs are
reported

cancer/
not reported

inhibits the
anti-
apoptotic
function of
Bcl2

not reported



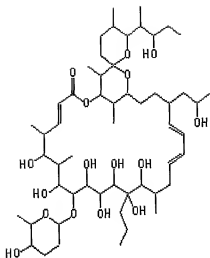
Gilvusmycin /
Streptomyces QM16

195052-09-6

cancer/
not reported

not reported

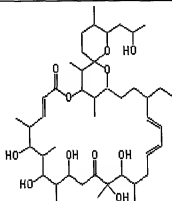
IC50's in ng/mL:
0.08 P388
0.86 K562 (CML)
0.72 A431 (EC)
0.75 MKN28 (GI);
(for all < 1 nM)



IB-96212/
marine actinomycete/
IB-96212

220858-11-7/
IB-96212;
IB-98214;
IB-97227
Cancer and
Antibacterial/
not reported

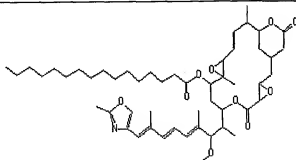
not reported IC50's in ng/mL:
0.1 P388



BE-56384²/
Streptomyces Sp./
BE-56384

207570-04-5 cancer/
not reported

not reported IC50's in ng/mL:
0.1 P388
0.29 colon 26
34 DLD-1
0.12 PC-13
0.12 MKM-45

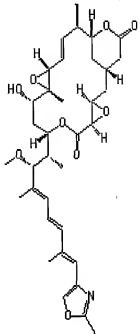


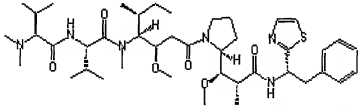
Palmitoylrhizoxin/

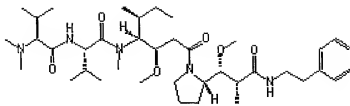
135819-69-1/ cancer/

tubulin

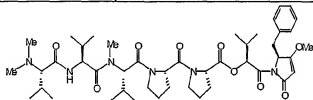
not reported

semi-synthetic; <i>Rhizopus chinensis</i>	Analog of rhizoxin	binds LDL; less cytotoxic than rhizoxin	binding agent (cell cycle inhibitor)
			
Rhizoxin/ <i>Rhizopus chinensis</i> WF-1360; NSC-332598; FR-900216	95917-95-6; 90996-54-6	melanoma, lung, CNS, colon, ovary, renal, breast, head and neck/ Rapid Drug clearance; High AUC correlates with high toxicity	tubulin binding agent (cell cycle inhibitor)
			NCI tumor panel (NSC 332598); log GI50's: 50 nM to 50 fM; log LC50's: 50 μM to 0.5 nM (several cell lines at 50 fM).

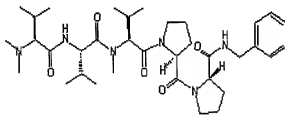
				
Dolastatin-10/ <i>Dolabella auricularia</i> (sea hare) NSC-376128	110417-88-4/ other Dolistatins (ie. 15) and analogs	prostate, melanoma, leukemia/ myelotoxicity (at greater than 0.3 pM)	tubulin binding agent (tubulin aggregation)	NCI tumor panel (60 cell line; GI50); 25 nM to 1 pM (most < 1 nM) (three cell lines μM)



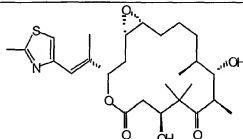
soblidotin/ synthetic/ TZT-1027; auristatin PE	149606-27-9/ analogues prepared	cancer (pancreas, esophageal colon, breast, lung, etc) / MTD was 1.8 mg/Kg (IV); toxicity not reported	tubulin binding agent	cell culture; colon, melanoma, M5076 tumors, P388 with 75- 85% inhibition (dose not reported)
--	---------------------------------------	---	-----------------------------	---



Dolastatin-15/ <i>Dolabella auricularia</i> (sea hare)	not reported/ other Dolastatins (ie. 15) and analogues	cancer/ not reported	Tubulin binding (tubuline aggregation)	NCI tumor panel (60 cell line; GI50); 25 nM to 39 pM (most < 1 nM) (one cell line 2.5 μM); most active in breast
--	--	-------------------------	---	---

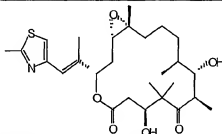


Cemadotin ⁴ / Synthetic; Parent Dolastatin-15 was isolated from <i>Dolabella auricularia</i> (sea hare)/ LU-103793; NSC D- 669356	1159776-69- 9/ many analogues	melanoma/ hypertension, myocardial ischemia and myelosuppression were dose-limiting toxicities.	tubulin binding (tubulin aggregation)	NCI tumor panel (NSC D-669356); active in breast, ovary, endometrial, sarcomas and drug resistant cell lines. Data not public.
---	-------------------------------------	---	--	---

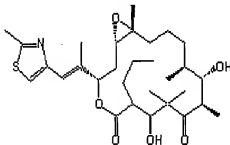


Epothilone A/	not reported/	cancer/	tubulin	IC50's of;
---------------	---------------	---------	---------	------------

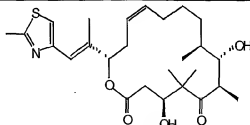
Synthetic or isolated from <i>Sorangium cellulosum</i> (myxococcales) strain So ce90)	many analogs	not reported	binding (tubulin polymeriza- tion)	1.5 nM MCF-7 (breast) 27.1 nM MCF-7/ADR 2.1 nM KB-31 (melanoma) 3.2 nM HCT-116
--	--------------	--------------	---	--



Epothilone B/ Synthetic or isolated from <i>Sorangium cellulosum</i> (myxococcales) strain So ce90) / EPO-906	152044054-7/ many analogs	Solid tumors (breast, ovarian, etc)/ well tolerated; t1/2 of 2.5 hrs; partial responses (phase I); diarrhea major side effect.	tubulin binding (tubulin polymeriza- tion)	IC50's of; 0.18 nM MCF-7 (breast) 2.92 nM MCF-7/ADR 0.19 nM KB-31 (melanoma) 0.42 nM HCT-116; broad activity reported
---	------------------------------	--	--	--



Epothilone Analog / Synthetic or semi- synthetic; Original lead, Epothilone A, isolated from <i>Sorangium</i> <i>cellulosum</i> (myxococcales) strain So ce90)/ ZK-EPO	not reported / hundreds of analogues	cancer/ not reported	tubulin binding (tubulin polymeriza- tion)	IC50's of 0.30 to 1.80 nM in various tumor cell lines; active in drug resistant cell lines
---	--	-------------------------	--	--



Epothilone D / Epothilone D, isolated from <i>Sorangium</i> <i>cellulosum</i>	189452-10-9/ many analogs	Solid tumors (breast, ovarian, etc)/ emesis and anemia; t1/2 of 5-10 hrs.	tubulin binding (tubulin polymeriza- tion)	NCI tumor panel (NSC- 703147; IC50); 0.19 nM KB-31 (melanoma)
---	------------------------------	--	--	--

(myxococcales) strain So
ce90/
KOS-862

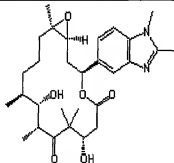
tion) 0.42 nM HCT-116;
broad activity reported

Structure Not Identified

Epothilone D analog^{5/}
Synthetic or semi-
synthetic; Original lead,
Epothilone D, isolated
from *Sorangium*
cellulosum
(myxococcales) strain So
ce90/
KOS-166-24

189453-10-9/
hundreds of
analogs Solid tumors;
not reported

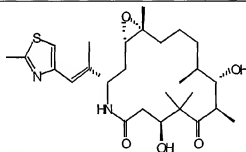
tubulin
binding
(tubulin
polymeriza-
tion) not reported



Epothilone Analog /
Synthetic; Original lead,
Epothilone A, isolated
from *Sorangium*
cellulosum
(myxococcales) strain So
ce90/
CGP-85715

not reported/
hundreds of
analogs cancer;
not reported

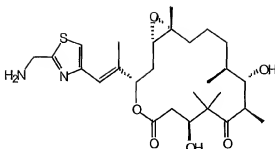
tubulin
binding
(tubulin
polymeriza-
tion) not reported



Epothilone Analog/
Synthetic or semi-
synthetic; Original lead,
Epothilone B, isolated
from *Sorangium*
cellulosum
(myxococcales) strain So
ce90/
BMS-247550

219989-84-1/
hundreds of
analogs non-small cell Lung,
breast, stomach tumor
(objective responses in
breast ovarian and lung)
sever toxicity (fatigue,
anorexia, nausea,
vomiting, neuropathy
myalgia)

tubulin
binding
(tubulin
polymeriza-
tion) NCI tumor Panel (NSC-
710428 & NSC-
710468); 8-32 nM
(NCI data not available)



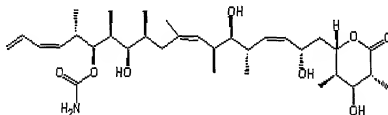
Epothilone Analog /
Synthetic or semi-
synthetic; Original lead,
Epothilone B, isolated
from *Sorangium*
cellulosum
(myxococcales) strain So
cc90/
BMS-310705

not reported/
hundreds of
analogues

advanced cancers/
adverse events (diarrhea,
nausea, vomiting,
fatigue, neutropenia);
t_{1/2} of 3.5 hrs;
improved water
solubility to BMS
247550.

tubulin
binding
(tubulin
polymeriza-
tion)

broad activity with
IC₅₀'s of 0.7 to 10 nM



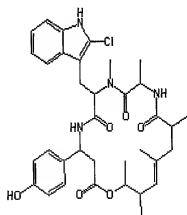
Discodermolide /
synthetic; originally
isolated from *Discodermia*
dissoluta (deep water
sponge); rare compound
(7 mg per 0.5 Kg sponge/
XAA-296

127943-53-7/
analogues less
potent

solid tumors/
not reported; 100-fold
increase in water
solubility over taxol

tubulin
stabilizing
agent
(similar to
taxol)

Broad activity (A549-
nsclung, prostate, P388,
ovarian with IC₅₀'s
about 10 nM) including
multi-drug resistant cell
lines;



Chondramide D/

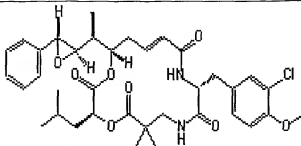
172430-63-6

cancer/

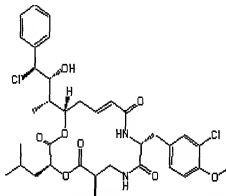
tubulin

5 nM A-549

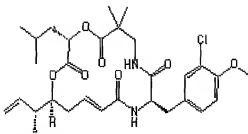
not reported	not reported	binding agent; actin polymerization inhibitor	(epidermoid carcinoma) 15 nM A-498 (kidney) 14 nM A549 (lung) 5 nM SK-OV-3 (ovary) 3 nM U-937 (lymphoma)
--------------	--------------	---	--



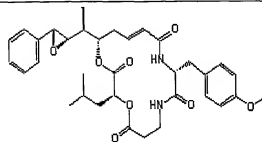
Cryptophycin analogs (including 52, 55 and others) ⁶¹ <i>Nostoc</i> sp GSV 224 (blue-green algae) isolated Cryptophycin 1./ LY-355703; Ly-355702; NSC-667642	204990-60-3 and 186256-67-7/ many potent analogs prepared at Lilly	solid tumors, colon cancer/ Phase II studies halted because of severe toxicity with one death resulting from drug;	tubulin polymerization inhibitor	broad activity (lung, breast, colon, leukemia) with IC50's of 2 to 40 pM; active against multi-drug resistance cell lines (resistant to MDR pump). NCI tumor panel, GI50's from 100 nM to 10 pM; LC50's from 100 nM to 25 pM.
--	---	---	----------------------------------	---



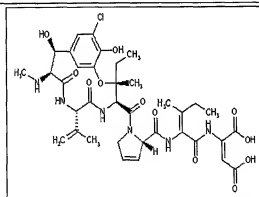
Cryptophycin 8/ semi-synthetic; starting material from <i>Nostoc</i> sp.	168482-36-8; 168482-40-4; 18665-94-1; 124689-65-2; 125546-14-7/ cryptophycin 5, 15 and 35	solid tumors/ not reported	tubulin polymerization inhibitor	broad spectrum anticancer activity (cell culture) including multi-drug resistant tumors
--	--	-------------------------------	----------------------------------	---



Cryptophycin analogs^{7/}
 synthetic; semi-synthetic,
 starting material from
Nostoc sp./
 LY-404291

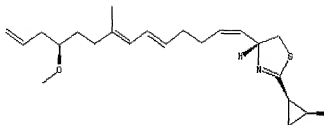


Arenastatin A analogs^{8/}
Dysidea arenaria (marine
 sponge)/
 Cryptophycin B; NSC-
 670038



**Phomopsin A/
Diaporthe toxicus or
Phomopsis
leptostromiformis (fungi)**

not reported Liver cancer (not as
 potent in other cancers)/
 not reported tubulin
 binding
 agent potent anticancer
 activity especially
 against liver cancer



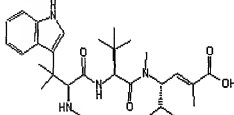
Curacin A and analogs/
Lyngbya majuscula (blue
green cyanobacterium)

155233-30-0/
analogs have
been prepared

Cancer/
not reported

Tubulin
binding
agent

broad activity (cancer
cell lines); 1-29 nM



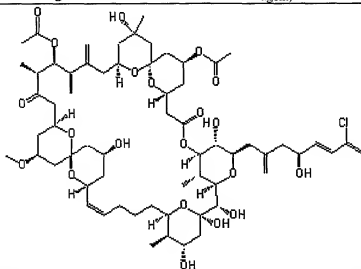
**Hemisterlins A & B
and analogs⁹/**
Cymbastela sp.

not reported/
criamide A &
B;
geodiamiolid-
G

Cancer/
not reported

Antimitotic
agent
(tubulin
binding
agent)

broad activity:
0.3-3 nM MCF7
(breast);
0.4 ng/mL P388

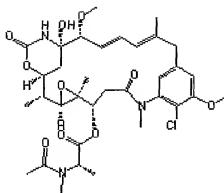


Spongistatins (1-9)¹⁰/
Spirastrell spintspirulifera
(sea sponge)

149715-96-8; cancer/
158734-18-0; not reported
158681-42-6;
158080-65-0;
150642-07-2;
153698-80-7;
153745-94-9;
150624-44-5;
158734-19-1/
other
spongistatins

tubulin
binding
agent

Most potent compounds
ever tested in NCI panel
cell line (mean GI50's
of 0.1 nM;
Spongistatin-1 GI50's
of 0.025-0.035 nM with
extremely potent
activity against a subset
of highly
chemoresistant tumor
types



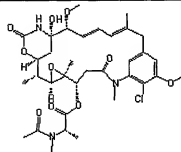
Maytansine/
Maytenus sp./
NSC-153858

35846-53-8/
other related
macrolides

cancer/
severe toxicity

tubulin
binding
agent (causes
extensive
disassembly
of the
microtubule
and totally
prevents
tubulin
spiralization)

Broad Activity in NCI
tumor panel (NSC-
153858; NSC-153858);
NCI tumor panel,
GI50's from 3 μ M to
0.1 pM; LC50's from
250 μ M to 10 pM. Two
different experiments
gave very different
potencies.



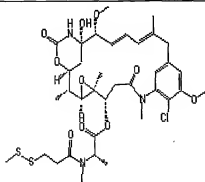
Maytansine-IgG(EGFR
directed)-conjugate^{11/}
semi-synthetic; starting
material from *Maytenus*
sp.

not reported/
other related
macrolides

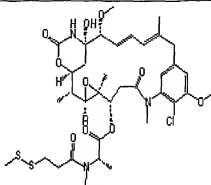
breast , head and neck,
Squamous cell
carcinoma/
not reported

EGFR
binding and
tubulin
binding

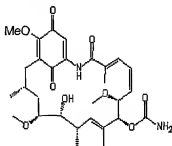
not reported



Maytansine-IgG(CD56 antigen)-conjugate ¹² , 3.5 drug molecules per IgG/ semi-synthetic; starting material from <i>Maytenus</i> sp./ huN901-DM1	not reported/ other related macrolides	Neuroendocrine, small-cell lung, carcinoma/ mild toxicity (fatigue, nausea, headaches and mild peripheral neuropathy); no hematological toxicity; MTD 60 mg/Kg, I.V., weekly for 4 weeks; only stable disease reported (humans)	CD56 binding and tubulin binding	antigen-specific cytotoxicity (cell culture; epidermal, breast, renal ovarian colon) with IC50's of 10-40 pM; animal studies (mice/SLC tumor--alone and in combination with taxol or cisplatin completely eliminated tumors).
---	--	---	----------------------------------	---

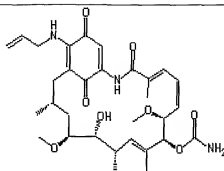


Maytansine-IgG(CEA antigen)-conjugate ¹³ , 4 drug molecules per IgG/ semi-synthetic; starting material from <i>Maytenus</i> sp./ C424-DM1	not reported/ other related macrolides	non-small-cell lung, carcinoma pancreas, lung, colon/ mild toxicity (fatigue, nausea, headaches and mild peripheral neuropathy); pancreatic lipase elevated; MTD 88 mg/Kg, I.V., every 21 days; only stable disease reported (humans); t1/2 was 44 hr.	CEA binding and tubulin binding	antigen-specific cytotoxicity (cell culture; epidermal, breast, renal ovarian colon) with IC50's of 10-40 pM; animal studies (mice: melanoma [COLO-205]--alone and in combination with taxol or cisplatin completely eliminated tumors);
--	--	--	---------------------------------	--



Geldanamycin / <i>Streptomyces hygroscopicus</i> var. Geldanus/ NSC-212518; Antibiotic U 29135; NSC-122750	30562-34-6/ natural derivatives	cancer/ not reported	binds Hsp 90 chaperone and inhibits function	NCI tumor panel (cell culture); 5.3 to 100 nM; most active in colon, lung and leukemia. NCI tumor panel, GI50's from 10 μM to 0.1 nM; LC50's from 100 μM to 100
--	---------------------------------------	-------------------------	--	---

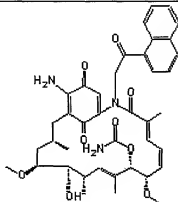
nM. Two assays with
very different potencies.



Geldanamycin Analog/
semi-synthetic; /
CP-127374; 17-AAG;
NSC-330507

745747-14-7/
Kosan, NCI
and UK
looking for
analogs with
longer t_{1/2}
and oral
activity;
analogs
include: NSC-
255110;
682300;
683661;
683663.

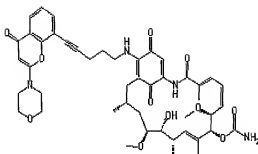
solid tumors/
Dose limiting toxicities
(anemia, anorexia,
diarrhea, nausea and
vomiting); t_{1/2} (i.v.) is
about 90 min; no
objective responses
measured at 88 mg/Kg
(i.v. daily for 5 days,
every 21 days);
binds Hsp 90 cell culture (not
chaperone reported); animal
models active (tumor
regression observed) in
breast, ovary,
melanoma, colon.



Geldanamycin analog/
semi-synthetic; /
CP-202567

not reported/
analogs
prepared
solid tumors/
not reported

binds Hsp 90 not reported
chaperone
and inhibits
function



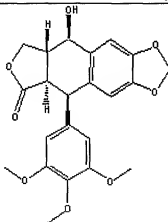
Geldanamycin conjugates/ semi-synthetic; / LY-294002-GM; PI3K-1- GM	345232-44-2/ analogs prepared	breast/ not reported	binds Hsp 90 chaperone and inhibits function; binds and inhibits PI-3 kinase	cell culture (no reported); animal models performed
---	-------------------------------------	-------------------------	--	---

Structure Not Reported

Geldanamycin Analog/ not reported/ CNF-101	not reported/ analogs prepared	breast, prostate/ not reported	binds Hsp 90 chaperone and inhibits function	not reported
---	--------------------------------------	-----------------------------------	---	--------------

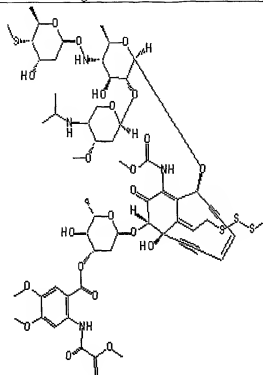
Structure Not Reported

Geldanamycin- testosterone conjugate/ semi-synthetic/ GMT-1	not reported/ analogs prepared	prostate/ not reported	binds Hsp 90 chaperone and inhibits function and testosterone receptors where it is internalized	not reported; conjugate has a 15-fold selective cytotoxicity for androgen positive prostate cells
--	--------------------------------------	---------------------------	---	---



Podophyllotoxin/ <i>Podophyllum</i> sp.	518-28-5/ many analogs	<i>Verruca vulgaris</i> , Condyloma/ severe toxicity when	tubulin inhibitor and topoisomer-	broad activity (cell culture) with IC50's in μ M range
---	---------------------------	---	---	--

given i.v. or s.c. ase inhibitor



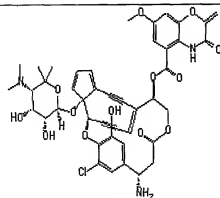
esperamicin-A1/
not known/
BBM-1675A1; BMY-
28175; GGM-1675

99674-26-7

cancer/
not reported (suspected
severe toxicity)

DNA
cleaving
agent

highly potent activity
(cell culture); animal
models highly potent
with optimal dose of
0.16 micrograms/Kg



C-1027¹⁴/
Streptomyces setonii C-
1027/
C-1027

120177-69-7

cancer (examined
hepatoma, breast, lung
and leukemia/
not reported

DNA
cleaving
agent

extremely potent (cell
culture) IC50's in pM
and fM; conjugated to
antibodies the potency
remains the same (ie.
5.5 to 42 pM);



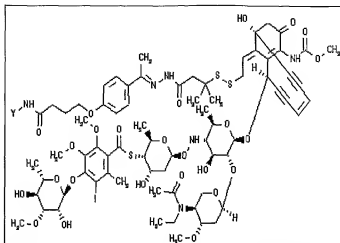
$m = 0.5 - 15$

Pr = proteinaceous carrier

W = calicheamicin minus Me-S-S-S

X = linker

Y = antibody P766



Calicheamicin-IgG(OBA1 antigen) conjugate/
semi-synthetic;
Micromonospora echinospora
OBA1-H8

not reported

cancer/
not reported

DNA
cleaving
agent

all human cancer; data
not reported



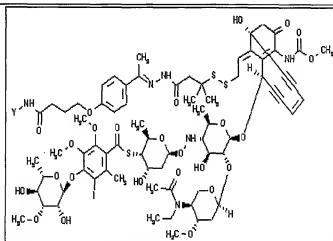
$m = 0.5 - 15$

Pr = proteinaceous carrier

W = calicheamicin minus Me-S-S-S

X = linker

Y = antibody P76.6



Calicheamicin-IgG(CD22 antigen) conjugate/
semi-synthetic;
Micromonospora echinospora
CMC-544

not reported

non-Hodgkin lymphoma,
cancer/
not reported

DNA
cleaving
agent

all human cancer; data
not reported

parially esterified polystyrene maleic acid copolymer (SMA)
conjugated to neocarzinostatin (NCS)

Neocarzinostatin^{17/}
semi-synthetic;
Streptomyces

123760-07-6; liver cancer and brain
9014-02-2 cancer/
not reported

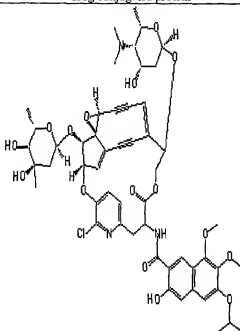
DNA
cleaving
agent

cell culture data not
reported.

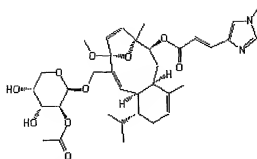
carconistaticus
Zinostatin stimalamer;
YM-881; YM-16881

IgG (TES-23)-conjugated to neocarzinostatin

Neocarzinostatin/ not reported/ TES-23-NCS	not reported	solid tumors/ toxicity not reported; the TES-23 antibody (without anticancer agent) was as effective at eliminating tumors as the drug conjugated protein	DNA cleaving agent and immunostim-	cell culture data not reported.
--	--------------	---	---	------------------------------------



Kedarcidin ^{18/} <i>Streptoallotetichus</i> sp NOV strain L5856, ATCC 53650/ NSC-646276	128512-40-3; 128512-39-0/ chromophore and protein conjugate	cancer/ not reported	DNA cleaving agent	cell culture (IC50's in ng/mL), 0.4 HCT116; 0.3 HCT116/VP35; 0.3 HCT116/VM46; 0.2 A2780; 1.3 A2780/DDP. animal models in P388 and B-16 melanoma. NCI tumor panel, GI50's from 50 μ M to 5 μ M.
---	---	-------------------------	--------------------------	--



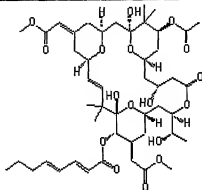
Eleutherobins/
marine coral

174545-76-7/
sarcodictyins
(marine coral)

cancer/
not reported

tubulin
binding
agent

similar potency to taxol;
not effective against
MDR cell lines

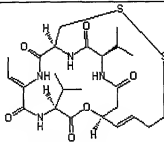


Bryostatin-1/
Bugula neritina (marine
bryozoan)/
GMY-45618; NSC-
339555

83314-01-6

leukemia, melanoma,
lung, cancer/
myalgia; accumulated
toxicity; poor water
solubility; dose limiting
toxicity

immunostim- not reported
ulant (TNF,
GM-CSF,
etc);
enhances cell
kill by
current
anticancer
agents



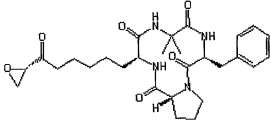
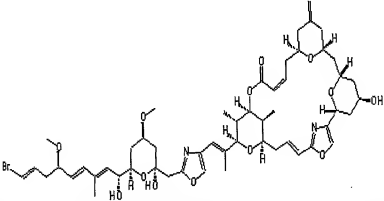
FR-901228/
Chromobacterium
violaceum strain 968/
NSC-63-176; FK-228

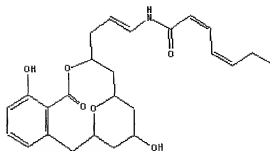
128517-07-7

leukemia, T-cell
lymphoma, cancer/
toxic doses (LD50) 6.4
and 10 mg/Kg, ip and iv
respectively; GI
toxicity, lymphoid
atrophy; dose limiting
toxicity (human) 18
mg/Kg; t1/2 of 8 hrs

histone
deacetylase
inhibitor

In vitro cell lines (NCI
tumor panel);
IC50's of between 0.56
and 4.1 nM (breast,
lung, gastric colon,
leukemia)

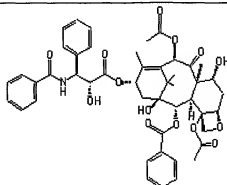
(human)				
				
Chlamydocin/ not reported	53342-16-8	cancer/ not reported	histone deacetylase inhibitor	not reported (cell culture); inhibits histone deacetylase at an IC50 of 1.3 nM
				
Phorbaxazole A ¹⁹ / marine sponge	181377-57-1; 165689-31-6; 180911-82-4; 165883-76-1/ analog prepared	leukemia, myeloma/ not reported	not reported (induces apoptosis)	NCI tumor panel (details not reported); IC50's of 1-10 nM. The inhibition values (clonogenic growth of human cancer cells) at 10 nM ranged from 6.2 to > 99.9% against NALM-6 human B- lineage acute lymphoblastic leukemia cells, BT-20 breast cancer cells and U373 glioblastoma cells, with the specified compound showing inhibition values in the range of 42.4 to > 99.9% against these cell lines.; IC50's are nM for MDR cell lines.



Apicularen A/
Chondromyces robustus

220757-06-2/
natural derivatives cancer/
not reported

not reported IC50's of 0.1 to 3
ng/mL (KB-3-A, KB-
Va, K562, HL60, U937,
A498, A549, PV3 and
SK-OV3)

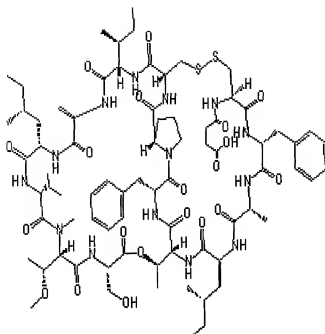


Taxol/
Pacific yew and fungi/
Paclitaxel; NSC-125973

33069624/
many analogs cancer; breast, prostate,
ovary, colon, lung, head
& neck, etc./
severe toxicity (grade III
and IV)

tubulin
binding
agent

NCI tumor panel;
GI50's of 3 nM to 1
μM;
TGI 50 nM to 25 μM

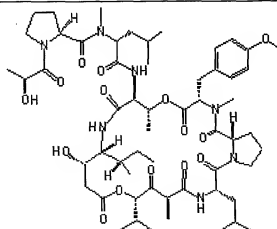


Vitilevuamide/
Didemnum cuculliferum
or *Polysyncrator*
lithostrotum

191681-63-7 cancer/
not reported

tubulin
binding
agent

cell culture; IC₅₀'s of
6-311 nM (panel of
tumor cell lines
HCT116 cells, A549
cells, SK-MEL-5 cells
A498 cells). The
increase in lifespan
(ILS) for CDF1 mice
after ip injection of
P388 tumor cells was in
the range of -45 to
+70% over the dose
range of 0.13 to 0.006
mg/kg.



Didemnin B/

77327-05-0; non-Hodgkin's

inhibits

NCI 60-tumor panel

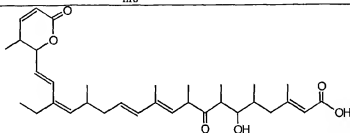
Trididemmun solidum/
NSC-2325319; IND
24505

77327-04-9;
77327-06-1/
other related
natural
products

lymphoma, breast,
carcinoma, CNS, colon/
Discontinued due to
cardiotoxicity; nausea,
neuro-muscular toxicity
and vomiting MTD 6.3
mg/Kg; toxicity
prevented achieving a
clinically signif. effect;
rapidly cleared (t_{1/2} 4.8
hrs

protein
synthesis via
EF-1

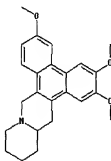
(GI50's): 100 nM to 50
fM.
Not potent against
MDR cell lines.



Leptomycin B/
Streptomyces sp. strain
ATS 1287/
NSC-364372; elactocin

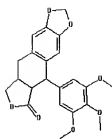
87081-35-4

NCI 60-tumor panel
(GI50's):
8 μ M to 1 pM; (LC50):
250 μ M to 10 nM
(several cell lines at 0.1
nM). Two testing
results with very
different potencies.



Cryptopleurin/
not known/
NSC-19912

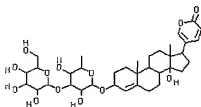
NCI 60-tumor panel
(GI50's): 19 nM to 1
pM; (LC50): 40 μ M to
10 nM (several cell
lines at 1 pM).



Silicicolin/
not known/
NSC-403148,
deoxypodophyllotoxin,
desoxypodophyllotoxin
podophyllotoxin,
deoxysilicicolin

19186-35-7

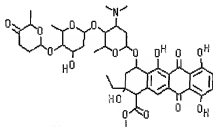
NCI 60-tumor panel
(GI50's): ~100 nM to 3
nM; (LC50): 50 μ M to
10 nM



Scillaren A/
not known/
NSC-7525; Gluco-
proscillaridin A;
Scillaren A

124-99-2

NCI 60-tumor panel
(GI50's): 50 nM to 0.1
nM;
(LC50): 250 μ M to 0.1
nM



Cinerubin A-HCl/
not known/
NSC-243022; Cinerubin
A hydrochloride;
CL 86-F2 HCl;
CL-86-F2-hydrochloride

not reported

NCI 60-tumor panel
(GI50's): 15 nM to 10
pM; (LC50): 100 μ M
to 6 nM

¹ WO-09739025; US-6025466² EP-00626383 30 November 1994³ JP-10101676⁴ WO-09705162; WO-09717364 (dolastatin synthesis and analogs)⁵ Kosan licensed patent for Epopthilone analogs from Sloan-Kettering; US 00185968

- ⁶ WO-09723211
- ⁷ WO-09723211
- ⁸ JP-08092232
- ⁹ WO-09633211
- ¹⁰ EP-00608111; EP-00632042; EP-00634414; WO-09748278
- ¹¹ EP-00425235; JP-53124692
- ¹² US-05416064; US-05208020; EP-00425235B
- ¹³ EP-004252351 JP-53124692; US-06333410B1
- ¹⁴ JP-1104183
- ¹⁵ EP-00689845
- ¹⁶ EP-00689845
- ¹⁷ EP-00136791; EP-00087957
- ¹⁸ US 50001112; US 5143906.
- ¹⁹ WO-00136048

Conventional immunotoxins contain an MAbs chemically conjugated to a toxin that is mutated or chemically modified to minimized binding to normal cells. Examples include anti-B4-blocked ricin, targeting CD5; and RFB4-deglycosylated ricin A chain, targeting CD22. Recombinant immunotoxins developed more recently are chimeric proteins consisting of the variable region of an antibody directed against a tumor antigen fused to a protein toxin using recombinant DNA technology. The toxin is also frequently genetically modified to remove normal tissue binding sites but retain its cytotoxicity. A large number of differentiation antigens, overexpressed receptors, or cancer-specific antigens have been identified as targets for immunotoxins, *e.g.*, CD19, CD22, CD20, IL-2 receptor (CD25), CD33, IL-4 receptor, EGF receptor and its mutants, ErbB2, Lewis carbohydrate, mesothelin, transferrin receptor, GM-CSF receptor, Ras, Bcr-Abl, and c-Kit, for the treatment of a variety of malignancies including hematopoietic cancers, glioma, and breast, colon, ovarian, bladder, and gastrointestinal cancers. *See e.g.*, Brinkmann et al., *Expert Opin. Biol. Ther.* 1:693-702 (2001); Perentesis and Sievers, *Hematology/Oncology Clinics of North America* 15:677-701 (2001).

MAbs conjugated with radioisotope are used as another means of treating human malignancies, particularly hematopoietic malignancies, with a high level of specificity and effectiveness. The most commonly used isotopes for therapy are the high-energy γ -emitters, such as ¹³¹I and ⁹⁰Y. Recently, ²¹³Bi-labeled anti-CD33 humanized MAb has also been tested in phase I human clinical trials. Reff et al., *supra*.

A number of MAbs have been used for therapeutic purposes. For example, the use of rituximab (Rituxan™), a recombinant chimeric anti-CD20 MAb, for treating certain

hematopoietic malignancies was approved by the FDA in 1997. Other MABs that have since been approved for therapeutic uses in treating human cancers include: alemtuzumab (Campath-1H™), a humanized rat antibody against CD52; and gemtuzumab ozogamicin (Mylotarg™), a calicheamicin-conjugated humanized mouse antiCD33 MAB. The FDA is also currently examining the safety and efficacy of several other MABs for the purpose of site-specific delivery of cytotoxic agents or radiation, e.g., radiolabeled Zevalin™ and Bexxar™. Reff et al., *supra*.

A second important consideration in designing a drug delivery system is the accessibility of a target tissue to a therapeutic agent. This is an issue of particular concern in the case of treating a disease of the central nervous system (CNS), where the blood-brain barrier prevents the diffusion of macromolecules. Several approaches have been developed to bypass the blood-brain barrier for effective delivery of therapeutic agents to the CNS.

The understanding of iron transport mechanism from plasma to brain provides a useful tool in bypassing the blood-brain barrier (BBB). Iron, transported in plasma by transferrin, is an essential component of virtually all types of cells. The brain needs iron for metabolic processes and receives iron through transferrin receptors located on brain capillary endothelial cells via receptor-mediated transcytosis and endocytosis. Moos and Morgan, *Cellular and Molecular Neurobiology* 20:77-95 (2000). Delivery systems based on transferrin-transferrin receptor interaction have been established for the efficient delivery of peptides, proteins, and liposomes into the brain. For example, peptides can be coupled with a MAB directed against the transferrin receptor to achieve greater uptake by the brain, Moos and Morgan, *Supra*. Similarly, when coupled with an MAB directed against the transferrin receptor, the transportation of basic fibroblast growth factor (bFGF) across the blood-brain barrier is enhanced. Song et al., *The Journal of Pharmacology and Experimental Therapeutics* 301:605-610 (2002); Wu et al., *Journal of Drug Targeting* 10:239-245 (2002). In addition, a liposomal delivery system for effective transport of the chemotherapy drug, doxorubicin, into C6 glioma has been reported, where transferrin was attached to the distal ends of liposomal PEG chains. Eavarone et al., *J. Biomed. Mater. Res.* 51:10-14 (2000). A number of US patents also relate to delivery methods bypassing the blood-brain barrier based on transferrin-transferrin receptor interaction. See e.g., US Patent Nos. 5,154,924; 5,182,107; 5,527,527; 5,833,988; 6,015,555.

There are other suitable conjugation partners for a pharmaceutical agent to bypass the blood-brain barrier. For example, US Patent Nos. 5,672,683, 5,977,307 and WO 95/02421 relate to a method of delivering a neuropharmaceutical agent across the blood-brain barrier, where the agent is administered in the form of a fusion protein with a ligand that is reactive with a brain capillary endothelial cell receptor; WO 99/00150 describes a drug delivery system in which the transportation of a drug across the blood-brain barrier is facilitated by conjugation with an MAb directed against human insulin receptor; WO 89/10134 describes a chimeric peptide, which includes a peptide capable of crossing the blood brain barrier at a relatively high rate and a hydrophilic neuropeptide incapable of transcytosis, as a means of introducing hydrophilic neuropeptides into the brain; WO 01/60411 A1 provides a pharmaceutical composition that can easily transport a pharmaceutically active ingredient into the brain. The active ingredient is bound to a hibernation-specific protein that is used as a conjugate, and administered with a thyroid hormone or a substance promoting thyroid hormone production. In addition, an alternative route of drug delivery for bypassing the blood-brain barrier has been explored. For instance, intranasal delivery of therapeutic agents without the need for conjugation has been shown to be a promising alternative delivery method (Frey, 2002, *Drug Delivery Technology*, 2(5):46-49).

In addition to facilitating the transportation of drugs across the blood-brain barrier, transferrin-transferrin receptor interaction is also useful for specific targeting of certain tumor cells, as many tumor cells overexpress transferrin receptor on their surface. This strategy has been used for delivering bioactive macromolecules into K562 cells via a transferrin conjugate (Wellhoner et al., *The Journal of Biological Chemistry* 266:4309-4314 (1991)), and for delivering insulin into enterocyte-like Caco-2 cells via a transferrin conjugate (Shah and Shen, *Journal of Pharmaceutical Sciences* 85:1306-1311 (1996)).

Furthermore, as more becomes known about the functions of various iron transport proteins, such as lactotransferrin receptor, melanotransferrin, ceruloplasmin, and Divalent Cation Transporter and their expression pattern, some of the proteins involved in iron transport mechanism (e.g., melanotransferrin), or their fragments, have been found to be similarly effective in assisting therapeutic agents transport across the blood-brain barrier or targeting specific tissues (WO 02/13843 A2, WO 02/13873 A2). For a review on the use of

transferrin and related proteins involved in iron uptake as conjugates in drug delivery, *see* Li and Qian, *Medical Research Reviews* 22:225-250 (2002).

The concept of tissue-specific delivery of therapeutic agents goes beyond the interaction between transferrin and transferrin receptor or their related proteins. For example, a bone-specific delivery system has been described in which proteins are conjugated with a bone-seeking aminobisphosphate for improved delivery of proteins to mineralized tissue. Uludag and Yang, *Biotechnol. Prog.* 18:604-611 (2002). For a review on this topic, *see* Vyas et al., *Critical Reviews in Therapeutic Drug Carrier System* 18:1-76 (2001).

A variety of linkers may be used in the process of generating bioconjugates for the purpose of specific delivery of therapeutic agents. Suitable linkers include homo- and heterobifunctional cross-linking reagents, which may be cleavable by, e.g., acid-catalyzed dissociation, or non-cleavable (*see, e.g.,* Srinivasachar and Neville, *Biochemistry* 28:2501-2509 (1989); Wellhoner et al., *The Journal of Biological Chemistry* 266:4309-4314 (1991)). Interaction between many known binding partners, such as biotin and avidin/streptavidin, can also be used as a means to join a therapeutic agent and a conjugate partner that ensures the specific and effective delivery of the therapeutic agent. Using the methods of the invention, proteins may be used to deliver molecules to intracellular compartments as conjugates. Proteins, peptides, hormones, cytokines, small molecules or the like that bind to specific cell surface receptors that are internalized after ligand binding may be used for intracellular targeting of conjugated therapeutic compounds. Typically, the receptor-ligand complex is internalized into intracellular vesicles that are delivered to specific cell compartments, including, but not limited to, the nucleus, mitochondria, golgi, ER, lysosome, and endosome, depending on the intracellular location targeted by the receptor. By conjugating the receptor ligand with the desired molecule, the drug will be carried with the receptor-ligand complex and be delivered to the intracellular compartments normally targeted by the receptor. The drug can therefore be delivered to a specific intracellular location in the cell where it is needed to treat a disease.

Many proteins may be used to target therapeutic agents to specific tissues and organs. Targeting proteins include, but are not limited to, growth factors (EPO, HGH, EGF, nerve growth factor, FGF, among others), cytokines (GM-CSF, G-CSF, the interferon family, interleukins, among others), hormones (FSH, LH, the steroid families, estrogen,

corticosteroids, insulin, among others), serum proteins (albumin, lipoproteins, fetoprotein, human serum proteins, antibodies and fragments of antibodies, among others), and vitamins (folate, vitamin C, vitamin A, among others). Targeting agents are available that are specific for receptors on most cells types.

Contemplated linkage configurations include, but are not limited to, protein-sugar-linker-sugar-protein and multivalent forms thereof, protein-sugar-linker-protein and multivalent forms thereof, protein-sugar-linker-therapeutic agent, where the therapeutic agent includes, but are not limited to, small molecules, peptides and lipids. In some embodiments, a hydrolysable linker is used that can be hydrolyzed once internalized. An acid labile linker can be used to advantage where the protein conjugate is internalized into the endosomes or lysosomes which have an acidic pH. Once internalized into the endosome or lysosome, the linker is hydrolyzed and the therapeutic agent is released from the targeting agent.

In an exemplary embodiment, transferrin is conjugated via a linker to an enzyme or a nucleic acid vector that encoded the enzyme desired to be targeted to a cell that presents transferrin receptors in a patient. The patient could, for example, require enzyme replacement therapy for that particular enzyme. In particularly preferred embodiments, the enzyme is one that is lacking in a patient with a lysosomal storage disease (see Table 5). Once in circulation, the transferrin-enzyme conjugate is linked to transferrin receptors and is internalized in early endosomes (Xing et al., 1998, *Biochem. J.* 336:667; Li et al., 2002, *Trends in Pharmacol. Sci.* 23:206; Suhaila et al., 1998, *J. Biol. Chem.* 273:14355). Other contemplated targeting agents that are related to transferrin include, but are not limited to, lactotransferrin (lactoferrin), melanotransferrin (p97), ceruloplasmin, and divalent cation transporter.

In another exemplary embodiment, transferrin-dystrophin conjugates would enter endosomes by the transferrin pathway. Once there, the dystrophin is released due to a hydrolysable linker which can then be taken to the intracellular compartment where it is required. This embodiment may be used to treat a patient with muscular dystrophy by supplementing a genetically defective dystrophin gene and/or protein with the functional dystrophin peptide connected to the transferrin.

E. Therapeutic Moieties

In another preferred embodiment, the modified sugar includes a therapeutic moiety. Those of skill in the art will appreciate that there is overlap between the category of therapeutic moieties and biomolecules; many biomolecules have therapeutic properties or potential.

The therapeutic moieties can be agents already accepted for clinical use or they can be drugs whose use is experimental, or whose activity or mechanism of action is under investigation. The therapeutic moieties can have a proven action in a given disease state or can be only hypothesized to show desirable action in a given disease state. In a preferred embodiment, the therapeutic moieties are compounds, which are being screened for their ability to interact with a tissue of choice. Therapeutic moieties, which are useful in practicing the instant invention include drugs from a broad range of drug classes having a variety of pharmacological activities. In some embodiments, it is preferred to use therapeutic moieties that are not sugars. An exception to this preference is the use of a sugar that is modified by covalent attachment of another entity, such as a PEG, biomolecule, therapeutic moiety, diagnostic moiety and the like. In an exemplary embodiment, an antisense nucleic acid moiety is conjugated to a linker arm which is attached to the targeting moiety. In another exemplary embodiment, a therapeutic sugar moiety is conjugated to a linker arm and the sugar-linker arm cassette is subsequently conjugated to a peptide via a method of the invention.

Methods of conjugating therapeutic and diagnostic agents to various other species are well known to those of skill in the art. See, for example Hermanson, BIOCONJUGATE TECHNIQUES, Academic Press, San Diego, 1996; and Dunn *et al.*, Eds. POLYMERIC DRUGS AND DRUG DELIVERY SYSTEMS, ACS Symposium Series Vol. 469, American Chemical Society, Washington, D.C. 1991.

In an exemplary embodiment, the therapeutic moiety is attached to the modified sugar via a linkage that is cleaved under selected conditions. Exemplary conditions include, but are not limited to, a selected pH (e.g., stomach, intestine, endocytotic vacuole), the presence of an active enzyme (e.g., esterase, protease, reductase, oxidase), light, heat and the like. Many cleavable groups are known in the art. See, for example, Jung *et al.*, *Biochem. Biophys. Acta*, **761**: 152-162 (1983); Joshi *et al.*, *J. Biol. Chem.*, **265**: 14518-14525 (1990); Zarling *et al.*, *J.*

Immunol., **124**: 913-920 (1980); Bouizar *et al.*, *Eur. J. Biochem.*, **155**: 141-147 (1986); Park *et al.*, *J. Biol. Chem.*, **261**: 205-210 (1986); Browning *et al.*, *J. Immunol.*, **143**: 1859-1867 (1989).

- Classes of useful therapeutic moieties include, for example, non-steroidal anti-inflammatory drugs (NSAIDS). The NSAIDS can, for example, be selected from the following categories: (*e.g.*, propionic acid derivatives, acetic acid derivatives, fenamic acid derivatives, biphenylcarboxylic acid derivatives and oxicams); steroidal anti-inflammatory drugs including hydrocortisone and the like; adjuvants; antihistaminic drugs (*e.g.*, chlorpheniramine, triprolidine); antitussive drugs (*e.g.*, dextromethorphan, codeine, caramiphen and carbetapentane); antipruritic drugs (*e.g.*, methdilazine and trimeprazine); anticholinergic drugs (*e.g.*, scopolamine, atropine, homatropine, levodopa); anti-emetic and antinauseant drugs (*e.g.*, cyclizine, meclizine, chlorpromazine, buclizine); anorexic drugs (*e.g.*, benzphetamine, phentermine, chlorphentermine, fenfluramine); central stimulant drugs (*e.g.*, amphetamine, methamphetamine, dextroamphetamine and methylphenidate);
- antiarrhythmic drugs (*e.g.*, propranolol, procainamide, disopyramide, quinidine, encainide);
- adrenergic blocker drugs (*e.g.*, metoprolol, acebutolol, betaxolol, labetalol and timolol);
- cardiotonic drugs (*e.g.*, milrinone, amrinone and dobutamine); antihypertensive drugs (*e.g.*, enalapril, clonidine, hydralazine, minoxidil, guanadrel, guanethidine); diuretic drugs (*e.g.*, amiloride and hydrochlorothiazide); vasodilator drugs (*e.g.*, diltiazem, amiodarone, isoxsuprine, nylidrin, tolazoline and verapamil); vasoconstrictor drugs (*e.g.*, dihydroergotamine, ergotamine and methylsergide); antiulcer drugs (*e.g.*, ranitidine and cimetidine); anesthetic drugs (*e.g.*, lidocaine, bupivacaine, chlorprocaine, dibucaine); antidepressant drugs (*e.g.*, imipramine, desipramine, amitriptyline, nortriptyline); tranquilizer and sedative drugs (*e.g.*, chlordiazepoxide, benactyzine, benzquinamide, flurazepam, hydroxyzine, loxapine and promazine); antipsychotic drugs (*e.g.*, chlorprothixene, fluphenazine, haloperidol, molindone, thioridazine and trifluoperazine); antimicrobial drugs (antibacterial, antifungal, antiprotozoal and antiviral drugs).

- Classes of useful therapeutic moieties include adjuvants. The adjuvants can, for example, be selected from keyhole lymphet hemocyanin conjugates, monophosphoryl lipid A, mycoplasma-derived lipopeptide MALP-2, cholera toxin B subunit, *Escherichia coli* heat-labile toxin, universal T helper epitope from tetanus toxoid, interleukin-12, CpG

oligodeoxynucleotides, dimethyldioctadecylammonium bromide, cyclodextrin, squalene, aluminum salts, meningococcal outer membrane vesicle (OMV), montanide ISA, TiterMax™ (available from Sigma, St. Louis MO), nitrocellulose absorption, immune-stimulating complexes such as Quil A, Gerbu™ adjuvant (Gerbu Biotechnik, Kirchwald, Germany),
5 threonyl muramyl dipeptide, thymosin alpha, bupivacaine, GM-CSF, Incomplete Freund's Adjuvant, MTP-PE/MF59 (Ciba/Geigy, Basel, Switzerland), polyphosphazene, saponin derived from the soapbark tree *Quillaja saponaria*, and Syntex adjuvant formulation (Biocine, Emeryville, CA), among others well known to those in the art.

Antimicrobial drugs which are preferred for incorporation into the present

- 10 composition include, for example, pharmaceutically acceptable salts of β -lactam drugs, quinolone drugs, ciprofloxacin, norfloxacin, tetracycline, erythromycin, amikacin, triclosan, doxycycline, capreomycin, chlorhexidine, chlortetracycline, oxytetracycline, clindamycin, ethambutol, hexamidine isothionate, metronidazole, pentamidine, gentamycin, kanamycin, lineomycin, methacycline, methenamine, minocycline, neomycin, netilmycin, paromomycin,
15 streptomycin, tobramycin, miconazole and amantadine.

Other drug moieties of use in practicing the present invention include antineoplastic drugs (e.g., antiandrogens (e.g., leuprolide or flutamide), cytotoxic agents (e.g., adriamycin, doxorubicin, taxol, cyclophosphamide, busulfan, cisplatin, β -2-interferon) anti-estrogens (e.g., tamoxifen), antimetabolites (e.g., fluorouracil, methotrexate, mercaptopurine,
20 thioguanine). Also included within this class are radioisotope-based agents for both diagnosis and therapy, and conjugated toxins, such as ricin, geldanamycin, mytansin, CC-1065, C-1027, the duocarmycins, calicheamycin and related structures and analogues thereof, and the toxins listed in Table 2.

- The therapeutic moiety can also be a hormone (e.g., medroxyprogesterone, estradiol,
25 leuprolide, megestrol, octreotide or somatostatin); muscle relaxant drugs (e.g., cinnamedrine, cyclobenzaprine, flavoxate, orphenadrine, papaverine, mebeverine, idaverine, ritodrine, diphenoxylate, dantrolene and azumolen); antispasmodic drugs; bone-active drugs (e.g., diphosphonate and phosphonoalkylphosphinate drug compounds); endocrine modulating drugs (e.g., contraceptives (e.g., ethinodiol, ethinyl estradiol, norethindrone, mestranol,
30 desogestrel, medroxyprogesterone), modulators of diabetes (e.g., glyburide or chlorpropamide), anabolics, such as testolactone or stanozolol, androgens (e.g.,

methyltestosterone, testosterone or fluoxymesterone), antidiuretics (*e.g.*, desmopressin) and calcitonins).

Also of use in the present invention are estrogens (*e.g.*, diethylstilbesterol), glucocorticoids (*e.g.*, triamcinolone, betamethasone, etc.) and progesterones, such as norethindrone, ethynodiol, norethindrone, levonorgestrel; thyroid agents (*e.g.*, liothyronine or levothyroxine) or anti-thyroid agents (*e.g.*, methimazole); antihyperprolactinemic drugs (*e.g.*, cabergoline); hormone suppressors (*e.g.*, danazol or goserelin), oxytocics (*e.g.*, methylergonovine or oxytocin) and prostaglandins, such as misoprostol, alprostadil or dinoprostone, can also be employed.

Other useful modifying groups include immunomodulating drugs (*e.g.*, antihistamines, mast cell stabilizers, such as lodoxamide and/or cromolyn, steroids (*e.g.*, triamcinolone, beclomethazone, cortisone, dexamethasone, prednisolone, methylprednisolone, beclomethasone, or clobetasol), histamine H₂ antagonists (*e.g.*, famotidine, cimetidine, ranitidine), immunosuppressants (*e.g.*, azathioprine, cyclosporin), etc. Groups with anti-inflammatory activity, such as sulindac, etodolac, ketoprofen and ketorolac, are also of use. Other drugs of use in conjunction with the present invention will be apparent to those of skill in the art.

Classes of useful therapeutic moieties include, for example, antisense drugs and also naked DNA. The antisense drugs can be selected from for example Affinitak (ISIS, Carlsbad, CA) and Genasense[™] (from Genta, Berkeley Heights, NJ). Naked DNA can be delivered as a gene therapy therapeutic for example with the DNA encoding for example factors VIII and IX for treatment of hemophilia disorders.

F. Preparation of Modified Sugars

Modified sugars useful in forming the conjugates of the invention are discussed herein. The discussion focuses on preparing a sugar modified with a water-soluble polymer for clarity of illustration. In particular, the discussion focuses on the preparation of modified sugars that include a poly(ethylene glycol) moiety. Those of skill will appreciate that the methods set forth herein are broadly applicable to the preparation of modified sugars, therefore, the discussion should not be interpreted as limiting the scope of the invention.

In general, the sugar moiety and the modifying group are linked together through the use of reactive groups, which are typically transformed by the linking process into a new organic functional group or unreactive species. The sugar reactive functional group(s), is located at any position on the sugar moiety. Reactive groups and classes of reactions useful in practicing the present invention are generally those that are well known in the art of bioconjugate chemistry. Currently favored classes of reactions available with reactive sugar moieties are those, which proceed under relatively mild conditions. These include, but are not limited to nucleophilic substitutions (e.g., reactions of amines and alcohols with acyl halides, active esters), electrophilic substitutions (e.g., enamine reactions) and additions to carbon-carbon and carbon-heteroatom multiple bonds (e.g., Michael reaction, Diels-Alder addition). These and other useful reactions are discussed in, for example, Smith and March, *ADVANCED ORGANIC CHEMISTRY*, 5th Ed., John Wiley & Sons, New York, 2001; Hermanson, *BIOCONJUGATE TECHNIQUES*, Academic Press, San Diego, 1996; and Feeney *et al.*, *MODIFICATION OF PROTEINS*; *Advances in Chemistry Series*, Vol. 198, American Chemical Society, Washington, D.C., 1982.

Useful reactive functional groups pendent from a sugar nucleus or modifying group include, but are not limited to:

(a) carboxyl groups and various derivatives thereof including, but not limited to, N-hydroxysuccinimide esters, N-hydroxybenzotriazole esters, acid halides, acyl imidazoles, thioesters, p-nitrophenyl esters, alkyl, alkenyl, alkynyl and aromatic esters;

(b) hydroxyl groups, which can be converted to, e.g., esters, ethers, aldehydes, etc.

(c) haloalkyl groups, wherein the halide can be later displaced with a nucleophilic group such as, for example, an amine, a carboxylate anion, thiol anion, carbanion, or an alkoxide ion, thereby resulting in the covalent attachment of a new group at the functional group of the halogen atom;

(d) dienophile groups, which are capable of participating in Diels-Alder reactions such as, for example, maleimido groups;

(e) aldehyde or ketone groups, such that subsequent derivatization is possible via formation of carbonyl derivatives such as, for example, imines, hydrazones, semicarbazones or oximes, or via such mechanisms as Grignard addition or alkyllithium addition;

(f) sulfonyl halide groups for subsequent reaction with amines, for example, to form sulfonamides;

(g) thiol groups, which can be, for example, converted to disulfides or reacted with alkyl and acyl halides;

5 (h) amine or sulfhydryl groups, which can be, for example, acylated, alkylated or oxidized;

(i) alkenes, which can undergo, for example, cycloadditions, acylation, Michael addition, *etc.*; and

(j) epoxides, which can react with, for example, amines and hydroxyl compounds.

10 The reactive functional groups can be chosen such that they do not participate in, or interfere with, the reactions necessary to assemble the reactive sugar nucleus or modifying group. Alternatively, a reactive functional group can be protected from participating in the reaction by the presence of a protecting group. Those of skill in the art understand how to protect a particular functional group such that it does not interfere with a chosen set of
15 reaction conditions. For examples of useful protecting groups, *see*, for example, Greene *et al.*, PROTECTIVE GROUPS IN ORGANIC SYNTHESIS, John Wiley & Sons, New York, 1991.

In the discussion that follows, a number of specific examples of modified sugars that are useful in practicing the present invention are set forth. In the exemplary embodiments, a sialic acid derivative is utilized as the sugar nucleus to which the modifying group is
20 attached. The focus of the discussion on sialic acid derivatives is for clarity of illustration only and should not be construed to limit the scope of the invention. Those of skill in the art will appreciate that a variety of other sugar moieties can be activated and derivatized in a manner analogous to that set forth using sialic acid as an example. For example, numerous methods are available for modifying galactose, glucose, N-acetylgalactosamine and fucose to
25 name a few sugar substrates, which are readily modified by art recognized methods. *See*, for example, Elhalabi *et al.*, *Curr. Med. Chem.* 6: 93 (1999); and Schafer *et al.*, *J. Org. Chem.* 65: 24 (2000).

In an exemplary embodiment, the peptide that is modified by a method of the invention is a peptide that is produced in mammalian cells (e.g., CHO cells) or in a transgenic
30 animal and thus, contains N- and/or O-linked oligosaccharide chains, which are incompletely sialylated. The oligosaccharide chains of the glycopeptide lacking a sialic acid and

containing a terminal galactose residue can be PEGylated, PPGylated or otherwise modified with a modified sialic acid.

In Scheme 4, the mannosamine glycoside **1**, is treated with the active ester of a protected amino acid (*e.g.*, glycine) derivative, converting the sugar amine residue into the corresponding protected amino acid amide adduct. The adduct is treated with an aldolase to form the sialic acid **2**. Compound **2** is converted to the corresponding CMP derivative by the action of CMP-SA synthetase, followed by catalytic hydrogenation of the CMP derivative to produce compound **3**. The amine introduced via formation of the glycine adduct is utilized as a locus of PEG or PPG attachment by reacting compound **3** with an activated PEG or PPG derivative (*e.g.*, PEG-C(O)NHS, PPG-C(O)NHS), producing **4** or **5**, respectively.

Scheme 4

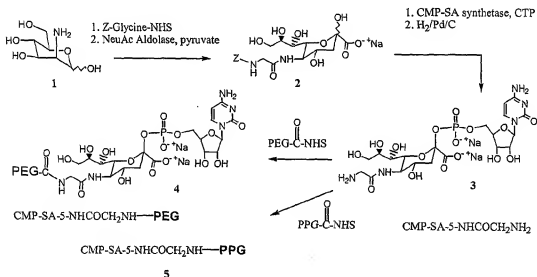
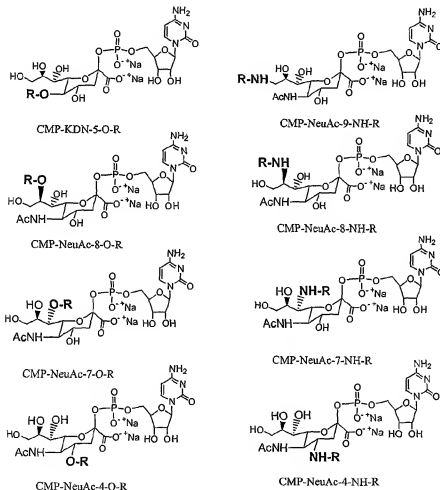
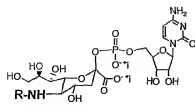


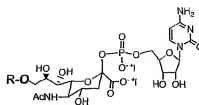
Table 3 sets forth representative examples of sugar monophosphates that are derivatized with a PEG or PPG moiety. Certain of the compounds of Table 3 are prepared by the method of Scheme 1. Other derivatives are prepared by art-recognized methods. See, for example, Keppler *et al.*, *Glycobiology* **11**: 11R (2001); and Charter *et al.*, *Glycobiology* **10**: 1049 (2000)). Other amine reactive PEG and PPG analogues are commercially available, or they can be prepared by methods readily accessible to those of skill in the art.

Table 3. Examples of sugar monophosphates that are derivatized with a PEG or PPG moiety





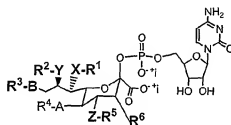
CMP-SA-5-NH-R



CMP-NeuAc-9-O-R

The modified sugar phosphates of use in practicing the present invention can be substituted in other positions as well as those set forth above. "i" may be Na or another salt and "i" may be interchangeable with Na. Presently preferred substitutions of sialic acid are set forth in Formula 5.

Formula 5:

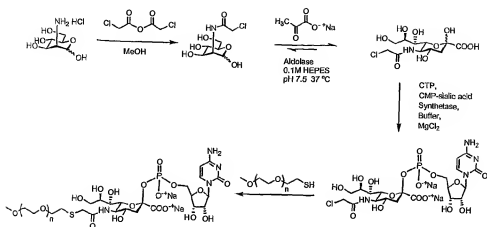


(I)

in which X is a linking group, which is preferably selected from $-O-$, $-N(H)-$, $-S-$, CH_2- , and $N(R)_2$, in which each R is a member independently selected from R^1-R^5 . "i" may be Na or another salt, and Na may be interchangeable with "i". The symbols Y, Z, A and B each represent a group that is selected from the group set forth above for the identity of X. X, Y, Z, A and B are each independently selected and, therefore, they can be the same or different. The symbols R^1 , R^2 , R^3 , R^4 and R^5 represent H, polymers, a water-soluble polymer, therapeutic moiety, biomolecule or other moiety. The symbol R^6 represents H, OH, or a polymer. Alternatively, these symbols represent a linker that is linked to a polymer, water-soluble polymer, therapeutic moiety, biomolecule or other moiety.

In another exemplary embodiment, a mannosamine is simultaneously acylated and activated for a nucleophilic substitution by the use of chloroacetic anhydride as set forth in Scheme 5. In each of the schemes presented in this section, i^+ or Na^+ can be interchangeable, wherein the salt can be sodium, or can be any other suitable salt.

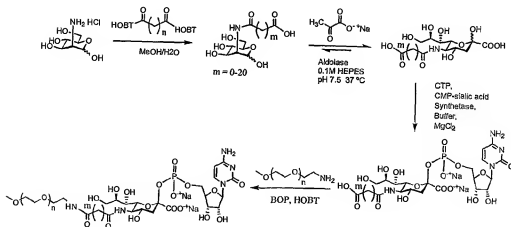
Scheme 5



The resulting chloro-derivatized glycan is contacted with pyruvate in the presence of an aldolase, forming a chloro-derivatized sialic acid. The corresponding nucleotide sugar is prepared by contacting the sialic acid derivative with an appropriate nucleotide triphosphates and a synthetase. The chloro group on the sialic acid moiety is then displaced with a nucleophilic PEG derivative, such as thio-PEG.

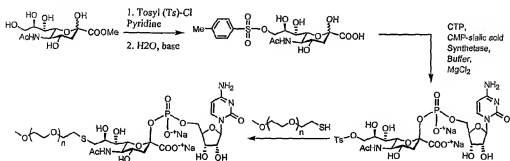
In a further exemplary embodiment, as shown in Scheme 6, a mannosamine is acylated with a bis-HOBT dicarboxylate, producing the corresponding amido-alkyl-carboxylic acid, which is subsequently converted to a sialic acid derivative. The sialic acid derivative is converted to a nucleotide sugar, and the carboxylic acid is activated and reacted with a nucleophilic PEG derivative, such as amino-PEG.

Scheme 6



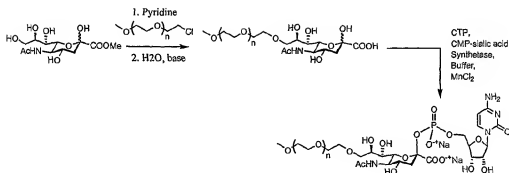
- In another exemplary embodiment, set forth in Scheme 7, amine- and carboxyl-protected neuraminic acid is activated by converting the primary hydroxyl group to the corresponding p-toluenesulfonate ester, and the methyl ester is cleaved. The activated neuraminic acid is converted to the corresponding nucleotide sugar, and the activating group is displaced by a nucleophilic PEG species, such as thio-PEG.

Scheme 7



- In yet a further exemplary embodiment, as set forth in Scheme 8, the primary hydroxyl moiety of an amine- and carboxyl-protected neuraminic acid derivative is alkylated using an electrophilic PEG, such as chloro-PEG. The methyl ester is subsequently cleaved and the PEG-sugar is converted to a nucleotide sugar.

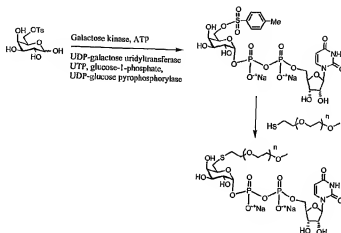
Scheme 8



- Glycans other than sialic acid can be derivatized with PEG using the methods set forth herein. The derivatized glycans, themselves, are also within the scope of the invention.
- Thus, Scheme 9 provides an exemplary synthetic route to a PEGylated galactose nucleotide

sugar. The primary hydroxyl group of galactose is activated as the corresponding toluenesulfonate ester, which is subsequently converted to a nucleotide sugar.

Scheme 9

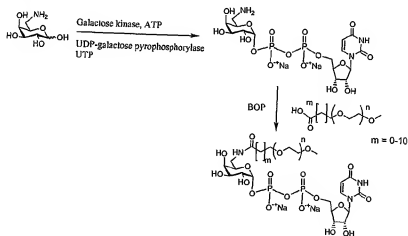


5

Scheme 10 sets forth an exemplary route for preparing a galactose-PEG derivative that is based upon a galactose-6-amine moiety. Thus, galactosamine is converted to a nucleotide sugar, and the amine moiety of galactosamine is functionalized with an active PEG derivative.

10

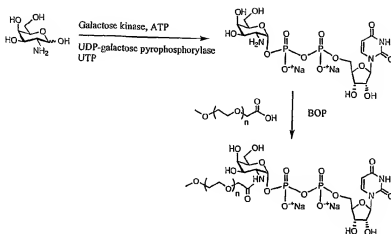
Scheme 10



Scheme 11 provides another exemplary route to galactose derivatives. The starting point for Scheme 11 is galactose-2-amine, which is converted to a nucleotide sugar. The amine moiety of the nucleotide sugar is the locus for attaching a PEG derivative, such as Methoxy-PEG (mPEG) carboxylic acid,

5

Scheme 11



Exemplary moieties attached to the conjugates disclosed herein include, but are not limited to, PEG derivatives (*e.g.*, acyl-PEG, acyl-alkyl-PEG, alkyl-acyl-PEG carbamoyl-PEG, aryl-PEG, alkyl-PEG), PPG derivatives (*e.g.*, acyl-PPG, acyl-alkyl-PPG, alkyl-acyl-PPG carbamoyl-PPG, aryl-PPG), polyapartic acid, polyglutamate, polylysine, therapeutic moieties, diagnostic moieties, mannose-6-phosphate, heparin, heparan, SLe^x, mannose, mannose-6-phosphate, Sialyl Lewis X, FGF, VFGF, proteins (*e.g.*, transferrin), chondroitin, keratan, dermatan, dextran, modified dextran, amylose, bisphosphate, poly-SA, hyaluronic acid, keratin, albumin, integrins, antennary oligosaccharides, peptides and the like. Methods of conjugating the various modifying groups to a saccharide moiety are readily accessible to those of skill in the art (POLY (ETHYLENE GLYCOL) CHEMISTRY : BIOTECHNICAL AND BIOMEDICAL APPLICATIONS, J. Milton Harris, Ed., Plenum Pub. Corp., 1992; POLY (ETHYLENE GLYCOL) CHEMICAL AND BIOLOGICAL APPLICATIONS, J. Milton Harris, Ed., ACS Symposium Series No. 680, American Chemical Society, 1997; Hermanson, BIOCONJUGATE TECHNIQUES, Academic Press, San Diego, 1996; and Dunn *et al.*, Eds. POLYMERIC DRUGS

AND DRUG DELIVERY SYSTEMS, ACS Symposium Series Vol. 469, American Chemical Society, Washington, D.C. 1991).

Purification of sugars, nucleotide sugars and derivatives

The nucleotide sugars and derivatives produced by the above processes can be used without purification. However, it is usually preferred to recover the product. Standard, well-known techniques for recovery of glycosylated saccharides such as thin or thick layer chromatography, column chromatography, ion exchange chromatography, or membrane filtration can be used. It is preferred to use membrane filtration, more preferably utilizing a reverse osmotic membrane, or one or more column chromatographic techniques for the recovery as is discussed hereinafter and in the literature cited herein. For instance, membrane filtration wherein the membranes have molecular weight cutoff of about 3000 to about 10,000 Da. Membrane filtration or reverse osmosis can then be used to remove salts and/or purify the product saccharides (*see, e.g.*, WO 98/15581). Nanofilter membranes are a class of reverse osmosis membranes that pass monovalent salts but retain polyvalent salts and uncharged solutes larger than about 100 to about 2,000 Daltons, depending upon the membrane used. Thus, in a typical application, saccharides prepared by the methods of the present invention will be retained in the membrane and contaminating salts will pass through.

G. Cross-linking Groups

Preparation of the modified sugar for use in the methods of the present invention includes attachment of a modifying group to a sugar residue and forming a stable adduct, which is a substrate for a glycosyltransferase. Thus, it is often preferred to use a cross-linking agent to conjugate the modifying group and the sugar. Exemplary bifunctional compounds which can be used for attaching modifying groups to carbohydrate moieties include, but are not limited to, bifunctional poly(ethylene glycols), polyamides, polyethers, polyesters and the like. General approaches for linking carbohydrates to other molecules are known in the literature. *See, for example, Lee et al., Biochemistry* **28**: 1856 (1989); Bhatia *et al., Anal. Biochem.* **178**: 408 (1989); Janda *et al., J. Am. Chem. Soc.* **112**: 8886 (1990) and Bednarski *et al.*, WO 92/18135. In the discussion that follows, the reactive groups are treated as benign on the sugar moiety of the nascent modified sugar. The focus of the discussion is

for clarity of illustration. Those of skill in the art will appreciate that the discussion is relevant to reactive groups on the modifying group as well.

5 An exemplary strategy involves incorporation of a protected sulfhydryl onto the sugar using the heterobifunctional crosslinker SPDP (n-succinimidyl-3-(2-pyridyldithio)propionate and then deprotecting the sulfhydryl for formation of a disulfide bond with another sulfhydryl on the modifying group.

If SPDP detrimentally affects the ability of the modified sugar to act as a glycosyltransferase substrate, one of an array of other crosslinkers such as 2-iminothiolane or N-succinimidyl S-acetylthioacetate (SATA) is used to form a disulfide bond. 2-
10 iminothiolane reacts with primary amines, instantly incorporating an unprotected sulfhydryl onto the amine-containing molecule. SATA also reacts with primary amines, but incorporates a protected sulfhydryl, which is later deacetylated using hydroxylamine to produce a free sulfhydryl. In each case, the incorporated sulfhydryl is free to react with other sulfhydryls or protected sulfhydryl, like SPDP, forming the required disulfide bond.

15 The above-described strategy is exemplary, and not limiting, of linkers of use in the invention. Other crosslinkers are available that can be used in different strategies for crosslinking the modifying group to the peptide. For example, TPCH(S-(2-thiopyridyl)-L-cysteine hydrazide and TPMPH ((S-(2-thiopyridyl) mercapto-propionohydrazide) react with carbohydrate moieties that have been previously oxidized by mild periodate treatment, thus
20 forming a hydrazone bond between the hydrazide portion of the crosslinker and the periodate generated aldehydes. TPCH and TPMPH introduce a 2-pyridylthione protected sulfhydryl group onto the sugar, which can be deprotected with DTT and then subsequently used for conjugation, such as forming disulfide bonds between components.

If disulfide bonding is found unsuitable for producing stable modified sugars, other
25 crosslinkers may be used that incorporate more stable bonds between components. The heterobifunctional crosslinkers GMBS (N-gama-malimidobutyryloxy)succinimide) and SMCC (succinimidyl 4-(N-maleimido-methyl)cyclohexane) react with primary amines, thus introducing a maleimide group onto the component. The maleimide group can subsequently react with sulfhydryls on the other component, which can be introduced by previously
30 mentioned crosslinkers, thus forming a stable thioether bond between the components. If steric hindrance between components interferes with either component's activity or the ability

of the modified sugar to act as a glycosyltransferase substrate, crosslinkers can be used which introduce long spacer arms between components and include derivatives of some of the previously mentioned crosslinkers (*i.e.*, SPDP). Thus, there is an abundance of suitable crosslinkers, which are useful; each of which is selected depending on the effects it has on optimal peptide conjugate and modified sugar production.

A variety of reagents are used to modify the components of the modified sugar with intramolecular chemical crosslinks (for reviews of crosslinking reagents and crosslinking procedures see: Wold, F., *Meth. Enzymol.* **25**: 623-651, 1972; Weetall, H. H., and Cooney, D. A., In: *ENZYMES AS DRUGS*. (Holcenberg, and Roberts, eds.) pp. 395-442, Wiley, New York, 1981; Ji, T. H., *Meth. Enzymol.* **91**: 580-609, 1983; Mattson *et al.*, *Mol. Biol. Rep.* **17**: 167-183, 1993, all of which are incorporated herein by reference). Preferred crosslinking reagents are derived from various zero-length, homo-bifunctional, and hetero-bifunctional crosslinking reagents. Zero-length crosslinking reagents include direct conjugation of two intrinsic chemical groups with no introduction of extrinsic material. Agents that catalyze formation of a disulfide bond belong to this category. Another example is reagents that induce condensation of a carboxyl and a primary amino group to form an amide bond such as carbodiimides, ethylchloroformate, Woodward's reagent K (2-ethyl-5-phenylisoxazolium-3'-sulfonate), and carbonyldiimidazole. In addition to these chemical reagents, the enzyme transglutaminase (glutamyl-peptide γ -glutamyltransferase; EC 2.3.2.13) may be used as zero-length crosslinking reagent. This enzyme catalyzes acyl transfer reactions at carboxamide groups of protein-linked glutaminyl residues, usually with a primary amino group as substrate. Preferred homo- and hetero-bifunctional reagents contain two identical or two dissimilar sites, respectively, which may be reactive for amino, sulfhydryl, guanidino, indole, or nonspecific groups.

2. Preferred Specific Sites in Crosslinking Reagents

a. Amino-Reactive Groups

In one preferred embodiment, the sites on the cross-linker are amino-reactive groups. Useful non-limiting examples of amino-reactive groups include N-hydroxysuccinimide (NHS) esters, imidoesters, isocyanates, acylhalides, arylazides, p-nitrophenyl esters, aldehydes, and sulfonyl chlorides.

NHS esters react preferentially with the primary (including aromatic) amino groups of a modified sugar component. The imidazole groups of histidines are known to compete with primary amines for reaction, but the reaction products are unstable and readily hydrolyzed. The reaction involves the nucleophilic attack of an amine on the acid carboxyl of an NHS ester to form an amide, releasing the N-hydroxysuccinimide. Thus, the positive charge of the original amino group is lost.

Imidoesters are the most specific acylating reagents for reaction with the amine groups of the modified sugar components. At a pH between 7 and 10, imidoesters react only with primary amines. Primary amines attack imidates nucleophilically to produce an intermediate that breaks down to amidine at high pH or to a new imidate at low pH. The new imidate can react with another primary amine, thus crosslinking two amino groups, a case of a putatively monofunctional imidate reacting bifunctionally. The principal product of reaction with primary amines is an amidine that is a stronger base than the original amine. The positive charge of the original amino group is therefore retained.

Isocyanates (and isothiocyanates) react with the primary amines of the modified sugar components to form stable bonds. Their reactions with sulfhydryl, imidazole, and tyrosyl groups give relatively unstable products.

Acylazides are also used as amino-specific reagents in which nucleophilic amines of the affinity component attack acidic carboxyl groups under slightly alkaline conditions, *e.g.* pH 8.5.

Arylhalides such as 1,5-difluoro-2,4-dinitrobenzene react preferentially with the amino groups and tyrosine phenolic groups of modified sugar components, but also with sulfhydryl and imidazole groups.

p-Nitrophenyl esters of mono- and dicarboxylic acids are also useful amino-reactive groups. Although the reagent specificity is not very high, α - and ϵ -amino groups appear to react most rapidly.

Aldehydes such as glutaraldehyde react with primary amines of modified sugar. Although unstable Schiff bases are formed upon reaction of the amino groups with the aldehydes of the aldehydes, glutaraldehyde is capable of modifying the modified sugar with stable crosslinks. At pH 6-8, the pH of typical crosslinking conditions, the cyclic polymers undergo a dehydration to form α - β unsaturated aldehyde polymers. Schiff bases, however,

are stable, when conjugated to another double bond. The resonant interaction of both double bonds prevents hydrolysis of the Schiff linkage. Furthermore, amines at high local concentrations can attack the ethylenic double bond to form a stable Michael addition product.

- 5 Aromatic sulfonyl chlorides react with a variety of sites of the modified sugar components, but reaction with the amino groups is the most important, resulting in a stable sulfonamide linkage.

b. Sulfhydryl-Reactive Groups

- 10 In another preferred embodiment, the sites are sulfhydryl-reactive groups. Useful, non-limiting examples of sulfhydryl-reactive groups include maleimides, alkyl halides, pyridyl disulfides, and thiophthalimides.

- Maleimides react preferentially with the sulfhydryl group of the modified sugar components to form stable thioether bonds. They also react at a much slower rate with
15 primary amino groups and the imidazole groups of histidines. However, at pH 7 the maleimide group can be considered a sulfhydryl-specific group, since at this pH the reaction rate of simple thiols is 1000-fold greater than that of the corresponding amine.

- Alkyl halides react with sulfhydryl groups, sulfides, imidazoles, and amino groups. At neutral to slightly alkaline pH, however, alkyl halides react primarily with sulfhydryl
20 groups to form stable thioether bonds. At higher pH, reaction with amino groups is favored.

Pyridyl disulfides react with free sulfhydryls via disulfide exchange to give mixed disulfides. As a result, pyridyl disulfides are the most specific sulfhydryl-reactive groups.

Thiophthalimides react with free sulfhydryl groups to form disulfides.

c. Carboxyl-Reactive Residue

- In another embodiment, carbodiimides soluble in both water and organic solvent, are used as carboxyl-reactive reagents. These compounds react with free carboxyl groups forming a pseudourea that can then coupled to available amines yielding an amide linkage. Procedures to modify a carboxyl group with carbodiimide is well know in the art (see,
30 Yamada *et al.*, *Biochemistry* **20**: 4836-4842, 1981).

3. Preferred Nonspecific Sites in Crosslinking Reagents

In addition to the use of site-specific reactive moieties, the present invention contemplates the use of non-specific reactive groups to link the sugar to the modifying group.

Exemplary non-specific cross-linkers include photoactivatable groups, completely

- 5 inert in the dark, which are converted to reactive species upon absorption of a photon of appropriate energy. In one preferred embodiment, photoactivatable groups are selected from precursors of nitrenes generated upon heating or photolysis of azides. Electron-deficient nitrenes are extremely reactive and can react with a variety of chemical bonds including N-H, O-H, C-H, and C=C. Although three types of azides (aryl, alkyl, and acyl derivatives) may
- 10 be employed, arylazides are presently preferred. The reactivity of arylazides upon photolysis is better with N-H and O-H than C-H bonds. Electron-deficient arylnitrenes rapidly ring-expand to form dehydroazepines, which tend to react with nucleophiles, rather than form C-H insertion products. The reactivity of arylazides can be increased by the presence of electron-withdrawing substituents such as nitro or hydroxyl groups in the ring. Such substituents push
- 15 the absorption maximum of arylazides to longer wavelength. Unsubstituted arylazides have an absorption maximum in the range of 260-280 nm, while hydroxy and nitroarylazides absorb significant light beyond 305 nm. Therefore, hydroxy and nitroarylazides are most preferable since they allow to employ less harmful photolysis conditions for the affinity component than unsubstituted arylazides.

- 20 In another preferred embodiment, photoactivatable groups are selected from fluorinated arylazides. The photolysis products of fluorinated arylazides are arylnitrenes, all of which undergo the characteristic reactions of this group, including C-H bond insertion, with high efficiency (Keana *et al.*, *J. Org. Chem.* 55: 3640-3647, 1990).

- In another embodiment, photoactivatable groups are selected from benzophenone
- 25 residues. Benzophenone reagents generally give higher crosslinking yields than arylazide reagents.

- In another embodiment, photoactivatable groups are selected from diazo compounds, which form an electron-deficient carbene upon photolysis. These carbenes undergo a variety of reactions including insertion into C-H bonds, addition to double bonds (including aromatic
- 30 systems), hydrogen attraction and coordination to nucleophilic centers to give carbon ions.

- In still another embodiment, photoactivatable groups are selected from diazopyruvates. For example, the p-nitrophenyl ester of p-nitrophenyl diazopyruvate reacts with aliphatic amines to give diazopyruvic acid amides that undergo ultraviolet photolysis to form aldehydes. The photolyzed diazopyruvate-modified affinity component will react like formaldehyde or glutaraldehyde forming crosslinks.

4. Homobifunctional Reagents

a. Homobifunctional crosslinkers reactive with primary amines

Synthesis, properties, and applications of amine-reactive cross-linkers are

- commercially described in the literature (for reviews of crosslinking procedures and reagents, *see above*). Many reagents are available (*e.g.*, Pierce Chemical Company, Rockford, Ill.; Sigma Chemical Company, St. Louis, Mo.; Molecular Probes, Inc., Eugene, OR.).

- Preferred, non-limiting examples of homobifunctional NHS esters include disuccinimidyl glutarate (DSG), disuccinimidyl suberate (DSS), bis(sulfosuccinimidyl) suberate (BS), disuccinimidyl tartarate (DST), disulfosuccinimidyl tartarate (sulfo-DST), bis-2-(succinimidooxycarbonyloxy)ethylsulfone (BSOCOES), bis-2-(sulfosuccinimidooxycarbonyloxy)ethylsulfone (sulfo-BSOCOES), ethylene glycolbis(succinimidylsuccinate) (EGS), ethylene glycolbis(sulfosuccinimidylsuccinate) (sulfo-EGS), dithiobis(succinimidylpropionate) (DSP), and dithiobis(sulfosuccinimidylpropionate) (sulfo-DSP). Preferred, non-limiting examples of homobifunctional imidoesters include dimethyl malonimide (DMM), dimethyl succinimide (DMSC), dimethyl adipimide (DMA), dimethyl pimelimide (DMP), dimethyl suberimide (DMS), dimethyl-3,3'-oxydipropionimide (DODP), dimethyl-3,3'-(methylenedioxy)dipropionimide (DMDP), dimethyl-3,3'-(dimethylenedioxy)dipropionimide (DDDP), dimethyl-3,3'-(tetramethylenedioxy)-dipropionimide (DTDP), and dimethyl-3,3'-dithiobispropionimide (DTBP).

Preferred, non-limiting examples of homobifunctional isothiocyanates include: p-phenylenediisothiocyanate (DITC), and 4,4'-diisothiocyano-2,2'-disulfonic acid stilbene (DIDS).

- Preferred, non-limiting examples of homobifunctional isocyanates include xylene-diisocyanate, toluene-2,4-diisocyanate, toluene-2-isocyanate-4-isothiocyanate, 3-

methoxydiphenylmethane-4,4'-diisocyanate, 2,2'-dicarboxy-4,4'-azophenyl diisocyanate, and hexamethylenediisocyanate.

Preferred, non-limiting examples of homobifunctional arylhalides include 1,5-difluoro-2,4-dinitrobenzene (DFDNB), and 4,4'-difluoro-3,3'-dinitrophenyl-sulfone.

- 5 Preferred, non-limiting examples of homobifunctional aliphatic aldehyde reagents include glyoxal, malondialdehyde, and glutaraldehyde.

Preferred, non-limiting examples of homobifunctional acylating reagents include nitrophenyl esters of dicarboxylic acids.

- 10 Preferred, non-limiting examples of homobifunctional aromatic sulfonyl chlorides include phenol-2,4-disulfonyl chloride, and α -naphthol-2,4-disulfonyl chloride.

Preferred, non-limiting examples of additional amino-reactive homobifunctional reagents include erythritolbiscarbonate which reacts with amines to give biscarbamates.

15 b. Homobifunctional Crosslinkers Reactive with Free Sulfhydryl Groups

Synthesis, properties, and applications of such reagents are described in the literature (for reviews of crosslinking procedures and reagents, *see above*). Many of the reagents are commercially available (e.g., Pierce Chemical Company, Rockford, Ill.; Sigma Chemical Company, St. Louis, Mo.; Molecular Probes, Inc., Eugene, OR).

- 20 Preferred, non-limiting examples of homobifunctional maleimides include bismaleimidohexane (BMH), N,N'-(1,3-phenylene) bismaleimide, N,N'-(1,2-phenylene)bismaleimide, azophenyldimaleimide, and bis(N-maleimidomethyl)ether.

Preferred, non-limiting examples of homobifunctional pyridyl disulfides include 1,4-di-3'-(2'-pyridyldithio)propionamidobutane (DPDPB).

- 25 Preferred, non-limiting examples of homobifunctional alkyl halides include 2,2'-dicarboxy-4,4'-diiodoacetamidoazobenzene, α , α' -diiodo-p-xylenesulfonic acid, α , α' -dibromo-p-xylenesulfonic acid, N,N'-bis(b-bromoethyl)benzylamine, N,N'-di(bromoacetyl)phenylhydrazine, and 1,2-di(bromoacetyl)amino-3-phenylpropane.

c. Homobifunctional Photoactivatable Crosslinkers

Synthesis, properties, and applications of such reagents are described in the literature (for reviews of crosslinking procedures and reagents, *see above*). Some of the reagents are commercially available (*e.g.*, Pierce Chemical Company, Rockford, Ill.; Sigma Chemical

Company, St. Louis, Mo.; Molecular Probes, Inc., Eugene, OR).

Preferred, non-limiting examples of homobifunctional photoactivatable crosslinker include bis- β -(4-azidosalicylamido)ethyldisulfide (BASED), di-N-(2-nitro-4-azidophenyl)-cystamine-S,S-dioxide (DNCO), and 4,4'-dithiobisphenylazide.

5. HeteroBifunctional Reagents

a. Amino-Reactive HeteroBifunctional Reagents with a Pyridyl Disulfide Moiety

Synthesis, properties, and applications of such reagents are described in the literature (for reviews of crosslinking procedures and reagents, *see above*). Many of the reagents are commercially available (*e.g.*, Pierce Chemical Company, Rockford, Ill.; Sigma Chemical Company, St. Louis, Mo.; Molecular Probes, Inc., Eugene, OR).

Preferred, non-limiting examples of hetero-bifunctional reagents with a pyridyl disulfide moiety and an amino-reactive NHS ester include N-succinimidyl-3-(2-pyridyldithio)propionate (SPDP), succinimidyl 6-3-(2-pyridyldithio)propionamido hexanoate (LC-SPDP), sulfosuccinimidyl 6-3-(2-pyridyldithio)propionamido hexanoate (sulfo-LCSPDP), 4-succinimidyl oxycarbonyl- α -methyl- α -(2-pyridyldithio)toluene (SMPT), and sulfosuccinimidyl 6- α -methyl- α -(2-pyridyldithio)toluamido hexanoate (sulfo-LC-SMPT).

b. Amino-Reactive HeteroBifunctional Reagents with a Maleimide Moiety

Synthesis, properties, and applications of such reagents are described in the literature. Preferred, non-limiting examples of hetero-bifunctional reagents with a maleimide moiety and an amino-reactive NHS ester include succinimidyl maleimidylacetate (AMAS), succinimidyl 3-maleimidylpropionate (BMPS), N- γ -maleimidobutyryloxysuccinimide ester (GMBS)N- γ -maleimidobutyryloxysulfo succinimide ester (sulfo-GMBS) succinimidyl 6-maleimidylhexanoate (EMCS), succinimidyl 3-maleimidylbenzoate (SMB),

- m-maleimidobenzoyl-N-hydroxysuccinimide ester (MBS), m-maleimidobenzoyl-N-hydroxysulfosuccinimide ester (sulfo-MBS), succinimidyl 4-(N-maleimidomethyl)-cyclohexane-1-carboxylate (SMCC), sulfosuccinimidyl 4-(N-maleimidomethyl)cyclohexane-1-carboxylate (sulfo-SMCC), succinimidyl 4-(p-maleimidophenyl)butyrate (SMPB), and sulfosuccinimidyl 4-(p-maleimidophenyl)butyrate (sulfo-SMPB).

c. Amino-Reactive HeteroBifunctional Reagents with an Alkyl Halide Moiety

Synthesis, properties, and applications of such reagents are described in the literature.

- 10 Preferred, non-limiting examples of hetero-bifunctional reagents with an alkyl halide moiety and an amino-reactive NHS ester include N-succinimidyl-(4-iodoacetyl)aminobenzoate (SIAB), sulfosuccinimidyl-(4-iodoacetyl)aminobenzoate (sulfo-SIAB), succinimidyl-6-(iodoacetyl)aminohexanoate (SIAX), succinimidyl-6-(6-((iodoacetyl)-amino)hexanoylamino)hexanoate (SIAXX), succinimidyl-6-(((4-(iodoacetyl)-amino)-methyl)-cyclohexane-1-carbonyl)aminohexanoate (SIACX), and succinimidyl-4-((iodoacetyl)-amino)methylcyclohexane-1-carboxylate (SIAC).

- A preferred example of a hetero-bifunctional reagent with an amino-reactive NHS ester and an alkyl dihalide moiety is N-hydroxysuccinimidyl 2,3-dibromopropionate (SDBP). SDBP introduces intramolecular crosslinks to the affinity component by conjugating its amino groups. The reactivity of the dibromopropionyl moiety towards primary amine groups is controlled by the reaction temperature (McKenzie *et al.*, *Protein Chem.* 7: 581-592 (1988)).

- Preferred, non-limiting examples of hetero-bifunctional reagents with an alkyl halide moiety and an amino-reactive p-nitrophenyl ester moiety include p-nitrophenyl iodoacetate (NPIA).

Other cross-linking agents are known to those of skill in the art. See, for example, Pomato *et al.*, U.S. Patent No. 5,965,106. It is within the abilities of one of skill in the art to choose an appropriate cross-linking agent for a particular application.

d. Cleavable Linker Groups

In yet a further embodiment, the linker group is provided with a group that can be cleaved to release the modifying group from the sugar residue. Many cleavable groups are known in the art. *See*, for example, Jung *et al.*, *Biochem. Biophys. Acta* **761**: 152-162 (1983); Joshi *et al.*, *J. Biol. Chem.* **265**: 14518-14525 (1990); Zarling *et al.*, *J. Immunol.* **124**: 913-920 (1980); Bouiziar *et al.*, *Eur. J. Biochem.* **155**: 141-147 (1986); Park *et al.*, *J. Biol. Chem.* **261**: 205-210 (1986); Browning *et al.*, *J. Immunol.* **143**: 1859-1867 (1989). Moreover a broad range of cleavable, bifunctional (both homo- and hetero-bifunctional) linker groups is commercially available from suppliers such as Pierce.

Exemplary cleavable moieties can be cleaved using light, heat or reagents such as thiols, hydroxylamine, bases, periodate and the like. Moreover, certain preferred groups are cleaved *in vivo* in response to being endocytosed (*e.g.*, cis-aconityl; *see*, Shen *et al.*, *Biochem. Biophys. Res. Commun.* **102**: 1048 (1991)). Preferred cleavable groups comprise a cleavable moiety which is a member selected from the group consisting of disulfide, ester, imide, carbonate, nitrobenzyl, phenacyl and benzoin groups.

e. Conjugation of Modified Sugars to Peptides

The modified sugars are conjugated to a glycosylated or non-glycosylated peptide using an appropriate enzyme to mediate the conjugation. Preferably, the concentrations of the modified donor sugar(s), enzyme(s) and acceptor peptide(s) are selected such that glycosylation proceeds until the acceptor is consumed. The considerations discussed below, while set forth in the context of a sialyltransferase, are generally applicable to other glycosyltransferase reactions.

A number of methods of using glycosyltransferases to synthesize desired oligosaccharide structures are known and are generally applicable to the instant invention. Exemplary methods are described, for instance, WO 96/32491, Ito *et al.*, *Pure Appl. Chem.* **65**: 753 (1993), and U.S. Pat. Nos. 5,352,670, 5,374,541, and 5,545,553.

The present invention is practiced using a single glycosyltransferase or a combination of glycosyltransferases. For example, one can use a combination of a sialyltransferase and a galactosyltransferase. In those embodiments using more than one enzyme, the enzymes and substrates are preferably combined in an initial reaction mixture, or the enzymes and reagents

for a second enzymatic reaction are added to the reaction medium once the first enzymatic reaction is complete or nearly complete. By conducting two enzymatic reactions in sequence in a single vessel, overall yields are improved over procedures in which an intermediate species is isolated. Moreover, cleanup and disposal of extra solvents and by-products is reduced.

In a preferred embodiment, each of the first and second enzyme is a glycosyltransferase. In another preferred embodiment, one enzyme is an endoglycosidase. In another preferred embodiment, one enzyme is an exoglycosidase. In an additional preferred embodiment, more than two enzymes are used to assemble the modified glycoprotein of the invention. The enzymes are used to alter a saccharide structure on the peptide at any point either before or after the addition of the modified sugar to the peptide.

In another embodiment, at least two of the enzymes are glycosyltransferases and the last sugar added to the saccharide structure of the peptide is a non-modified sugar. Instead, the modified sugar is internal to the glycan structure and therefore need not be the ultimate sugar on the glycan. In an exemplary embodiment, galactosyltransferase may catalyze the transfer of Gal-PEG from UDP-Gal-PEG onto the glycan, followed by incubation in the presence of ST3Gal3 and CMP-SA, which serves to add a "capping" unmodified sialic acid onto the glycan (Figure 23A).

In another embodiment, at least two of the enzymes used are glycosyltransferases, and at least two modified sugars are added to the glycan structures on the peptide. In this manner, two or more different glycoconjugates may be added to one or more glycans on a peptide. This process generates glycan structures having two or more functionally different modified sugars. In an exemplary embodiment, incubation of the peptide with GnT-I, II and UDP-GlcNAc-PEG serves to add a GlcNAc-PEG molecule to the glycan; incubation with galactosyltransferase and UDP-Gal then serves to add a Gal residue thereto; and, incubation with ST3Gal3 and CMP-SA-Man-6-Phosphate serves to add a SA-mannose-6-phosphate molecule to the glycan. This series of reactions results in a glycan chain having the functional characteristics of a PEGylated glycan as well as mannose-6-phosphate targeting activity (Figure 23B).

In another embodiment, at least two of the enzymes used in the reaction are glycosyltransferases, and again, different modified sugars are added to N-linked and O-

linked glycans on the peptide. This embodiment is useful when two different modified sugars are to be added to the glycans of a peptide, but when it is important to spatially separate the modified sugars on the peptide from each other. For example, if the modified sugars comprise bulky molecules, including but not limited to, PEG and other molecules such as a linker molecule, this method may be preferable. The modified sugars may be added simultaneously to the glycan structures on a peptide, or they may be added sequentially. In an exemplary embodiment, incubation with ST3Gal3 and CMP-SA-PEG serves to add sialic acid-PEG to the N-linked glycans, while incubation with ST3Gal1 and CMP-SA-bisPhosphonate serves to add sialic acid-BisPhosphonate to the O-linked glycans (Figure 23C).

In another embodiment, the method makes use of one or more exo- or endoglycosidase. The glycosidase is typically a mutant, which is engineered to form glycosyl bonds rather than rupture them. The mutant glycanase, sometimes called a glycosynthase, typically includes a substitution of an amino acid residue for an active site acidic amino acid residue. For example, when the endoglycanase is endo-H, the substituted active site residues will typically be Asp at position 130, Glu at position 132 or a combination thereof. The amino acids are generally replaced with serine, alanine, asparagine, or glutamine. Exoglycosidases such as transglycosylase are also useful.

The mutant enzyme catalyzes the reaction, usually by a synthesis step that is analogous to the reverse reaction of the endoglycanase hydrolysis step. In these embodiments, the glycosyl donor molecule (e.g., a desired oligo- or mono-saccharide structure) contains a leaving group and the reaction proceeds with the addition of the donor molecule to a GlcNAc residue on the protein. For example, the leaving group can be a halogen, such as fluoride. In other embodiments, the leaving group is a Asn, or a Asn-peptide moiety. In yet further embodiments, the GlcNAc residue on the glycosyl donor molecule is modified. For example, the GlcNAc residue may comprise a 1,2 oxazoline moiety.

In a preferred embodiment, each of the enzymes utilized to produce a conjugate of the invention are present in a catalytic amount. The catalytic amount of a particular enzyme varies according to the concentration of that enzyme's substrate as well as to reaction conditions such as temperature, time and pH value. Means for determining the catalytic

amount for a given enzyme under preselected substrate concentrations and reaction conditions are well known to those of skill in the art.

The temperature at which an above-described process is carried out can range from just above freezing to the temperature at which the most sensitive enzyme denatures.

- 5 Preferred temperature ranges are about 0 °C to about 55 °C, and more preferably about 20 °C to about 37 °C. In another exemplary embodiment, one or more components of the present method are conducted at an elevated temperature using a thermophilic enzyme.

- 10 The reaction mixture is maintained for a period of time sufficient for the acceptor to be glycosylated, thereby forming the desired conjugate. Some of the conjugate can often be detected after a few hours, with recoverable amounts usually being obtained within 24 hours or less. Those of skill in the art understand that the rate of reaction is dependent on a number of variable factors (e.g., enzyme concentration, donor concentration, acceptor concentration, temperature, solvent volume), which are optimized for a selected system.

- 15 The present invention also provides for the industrial-scale production of modified peptides. As used herein, an industrial scale generally produces at least one gram of finished, purified conjugate.

- In the discussion that follows, the invention is exemplified by the conjugation of modified sialic acid moieties to a glycosylated peptide. The exemplary modified sialic acid is labeled with PEG. The focus of the following discussion on the use of PEG-modified sialic acid and glycosylated peptides is for clarity of illustration and is not intended to imply that the invention is limited to the conjugation of these two partners. One of skill understands that the discussion is generally applicable to the additions of modified glycosyl moieties other than sialic acid. Moreover, the discussion is equally applicable to the modification of a glycosyl unit with agents other than PEG including other water-soluble polymers, therapeutic moieties, and biomolecules.
- 20
- 25

- An enzymatic approach can be used for the selective introduction of PEGylated or PPGylated carbohydrates onto a peptide or glycopeptide. The method utilizes modified sugars containing PEG, PPG, or a masked reactive functional group, and is combined with the appropriate glycosyltransferase or glycosynthase. By selecting the glycosyltransferase that will make the desired carbohydrate linkage and utilizing the modified sugar as the donor substrate, the PEG or PPG can be introduced directly onto the peptide backbone, onto
- 30

existing sugar residues of a glycopeptide or onto sugar residues that have been added to a peptide.

An acceptor for the sialyltransferase is present on the peptide to be modified by the methods of the present invention either as a naturally occurring structure or one placed there recombinantly, enzymatically or chemically. Suitable acceptors, include, for example, galactosyl acceptors such as Gal β 1,4GlcNAc, Gal β 1,4GalNAc, Gal β 1,3GalNAc, lacto-N-tetraose, Gal β 1,3GlcNAc, Gal β 1,3Ara, Gal β 1,6GlcNAc, Gal β 1,4Glc (lactose), and other acceptors known to those of skill in the art (*see, e.g., Paulson et al., J. Biol. Chem.* **253**: 5617-5624 (1978)).

In one embodiment, an acceptor for the sialyltransferase is present on the peptide to be modified upon *in vivo* synthesis of the peptide. Such peptides can be sialylated using the claimed methods without prior modification of the glycosylation pattern of the peptide. Alternatively, the methods of the invention can be used to sialylate a peptide that does not include a suitable acceptor; one first modifies the peptide to include an acceptor by methods known to those of skill in the art. In an exemplary embodiment, a GalNAc residue is added by the action of a GalNAc transferase.

In an exemplary embodiment, the galactosyl acceptor is assembled by attaching a galactose residue to an appropriate acceptor linked to the peptide, *e.g.,* a GlcNAc. The method includes incubating the peptide to be modified with a reaction mixture that contains a suitable amount of a galactosyltransferase (*e.g.,* gal β 1,3 or gal β 1,4), and a suitable galactosyl donor (*e.g.,* UDP-galactose). The reaction is allowed to proceed substantially to completion or, alternatively, the reaction is terminated when a preselected amount of the galactose residue is added. Other methods of assembling a selected saccharide acceptor will be apparent to those of skill in the art.

In yet another embodiment, peptide-linked oligosaccharides are first "trimmed," either in whole or in part, to expose either an acceptor for the sialyltransferase or a moiety to which one or more appropriate residues can be added to obtain a suitable acceptor. Enzymes such as glycosyltransferases and endoglycosidases (*see, for example* U.S. Patent No. 5,716,812) are useful for the attaching and trimming reactions. A detailed discussion of "trimming" and remodeling N-linked and O-linked glycans is provided elsewhere herein.

In the discussion that follows, the method of the invention is exemplified by the use of modified sugars having a water-soluble polymer attached thereto. The focus of the discussion is for clarity of illustration. Those of skill will appreciate that the discussion is equally relevant to those embodiments in which the modified sugar bears a therapeutic moiety, biomolecule or the like.

An exemplary embodiment of the invention in which a carbohydrate residue is "trimmed" prior to the addition of the modified sugar is set forth in Figure 14, which sets forth a scheme in which high mannose is trimmed back to the first generation biantennary structure. A modified sugar bearing a water-soluble polymer is conjugated to one or more of the sugar residues exposed by the "trimming back." In one example, a water-soluble polymer is added via a GlcNAc moiety conjugated to the water-soluble polymer. The modified GlcNAc is attached to one or both of the terminal mannose residues of the biantennary structure. Alternatively, an unmodified GlcNAc can be added to one or both of the termini of the branched species.

In another exemplary embodiment, a water-soluble polymer is added to one or both of the terminal mannose residues of the biantennary structure via a modified sugar having a galactose residue, which is conjugated to a GlcNAc residue added onto the terminal mannose residues. Alternatively, an unmodified Gal can be added to one or both terminal GlcNAc residues.

In yet a further example, a water-soluble polymer is added onto a Gal residue using a modified sialic acid.

Another exemplary embodiment is set forth in Figure 15, which displays a scheme similar to that shown in Figure 14, in which the high mannose structure is "trimmed back" to the mannose from which the biantennary structure branches. In one example, a water-soluble polymer is added via a GlcNAc modified with the polymer. Alternatively, an unmodified GlcNAc is added to the mannose, followed by a Gal with an attached water-soluble polymer. In yet another embodiment, unmodified GlcNAc and Gal residues are sequentially added to the mannose, followed by a sialic acid moiety modified with a water-soluble polymer.

Figure 16 sets forth a further exemplary embodiment using a scheme similar to that shown in Figure 14, in which high mannose is "trimmed back" to the GlcNAc to which the first mannose is attached. The GlcNAc is conjugated to a Gal residue bearing a water-soluble

polymer. Alternatively, an unmodified Gal is added to the GlcNAc, followed by the addition of a sialic acid modified with a water-soluble sugar. In yet a further example, the terminal GlcNAc is conjugated with Gal and the GlcNAc is subsequently fucosylated with a modified fucose bearing a water-soluble polymer.

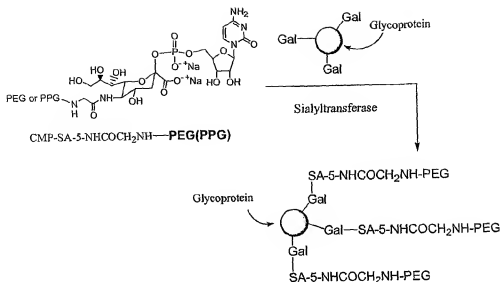
Figure 17 is a scheme similar to that shown in Figure 14, in which high mannose is trimmed back to the first GlcNAc attached to the Asn of the peptide. In one example, the GlcNAc of the GlcNAc-(Fuc)_n residue is conjugated with a GlcNAc bearing a water soluble polymer. In another example, the GlcNAc of the GlcNAc-(Fuc)_n residue is modified with Gal, which bears a water soluble polymer. In a still further embodiment, the GlcNAc is modified with Gal, followed by conjugation to the Gal of a sialic acid modified with a water-soluble polymer.

Other exemplary embodiments are set forth in Figures 18-22. An illustration of the array of reaction types with which the present invention may be practiced is provided in each of the aforementioned figures.

The Examples set forth above provide an illustration of the power of the methods set forth herein. Using the methods of the invention, it is possible to "trim back" and build up a carbohydrate residue of substantially any desired structure. The modified sugar can be added to the termini of the carbohydrate moiety as set forth above, or it can be intermediate between the peptide core and the terminus of the carbohydrate.

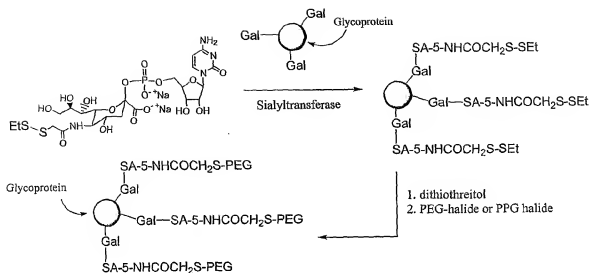
In an exemplary embodiment, an existing sialic acid is removed from a glycopeptide using a sialidase, thereby unmasking all or most of the underlying galactosyl residues. Alternatively, a peptide or glycopeptide is labeled with galactose residues, or an oligosaccharide residue that terminates in a galactose unit. Following the exposure of or addition of the galactose residues, an appropriate sialyltransferase is used to add a modified sialic acid. The approach is summarized in Scheme 12.

Scheme 12



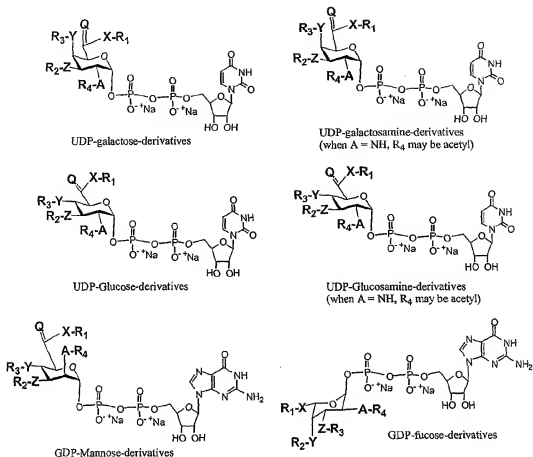
In yet a further approach, summarized in Scheme 13, a masked reactive functionality
 5 is present on the sialic acid. The masked reactive group is preferably unaffected by the
 conditions used to attach the modified sialic acid to the peptide. After the covalent
 attachment of the modified sialic acid to the peptide, the mask is removed and the peptide is
 conjugated with an agent such as PEG, PPG, a therapeutic moiety, biomolecule or other
 agent. The agent is conjugated to the peptide in a specific manner by its reaction with the
 10 unmasked reactive group on the modified sugar residue.

Scheme 13



- 5 Any modified sugar can be used with its appropriate glycosyltransferase, depending on the terminal sugars of the oligosaccharide side chains of the glycopeptide (Table 4). As discussed above, the terminal sugar of the glycopeptide required for introduction of the PEGylated or PPGylated structure can be introduced naturally during expression or it can be produced post expression using the appropriate glycosidase(s), glycosyltransferase(s) or mix
- 10 of glycosidase(s) and glycosyltransferase(s).

Table 4. Modified sugars.



X = O, NH, S, CH₂, N-(R₁-)₂.

Y = X; Z = X; A = X; B = X.

Q = H₂O, S, NH, N-R.

R, R₁₋₄ = H, Linker-M, M.

M = Ligand of interest

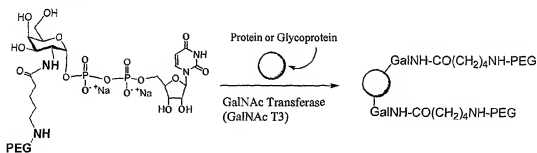
Ligand of interest = acyl-PEG, acyl-PPG, alkyl-PEG, acyl-alkyl-PEG, acyl-alkyl-PEG, carbamoyl-PEG, carbamoyl-PPG, PEG, PPG, acyl-aryl-PEG, acyl-aryl-PPG, aryl-PEG, aryl-PPG, Mannose-*g*-phosphate, heparin, heparan, SLex, Mannose, FGF, VPGF, protein, chondroitin, keratan, dermatan, albumin, integrins, peptides, etc.

- In a further exemplary embodiment, UDP-galactose-PEG is reacted with bovine milk β 1,4-galactosyltransferase, thereby transferring the modified galactose to the appropriate terminal N-acetylglucosamine structure. The terminal GlcNAc residues on the glycopeptide may be produced during expression, as may occur in such expression systems as mammalian, insect, plant or fungus, but also can be produced by treating the glycopeptide with a sialidase and/or glycosidase and/or glycosyltransferase, as required.

In another exemplary embodiment, a GlcNAc transferase, such as GnT-I-IV, is utilized to transfer PEGylated-GlcNAc to a mannose residue on a glycopeptide. In a still further exemplary embodiment, the N- and/or O-linked glycan structures are enzymatically removed from a glycopeptide to expose an amino acid or a terminal glycosyl residue that is subsequently conjugated with the modified sugar. For example, an endoglycanase is used to remove the N-linked structures of a glycopeptide to expose a terminal GlcNAc as a GlcNAc-linked-Asn on the glycopeptide. UDP-Gal-PEG and the appropriate galactosyltransferase is used to introduce the PEG- or PPG-galactose functionality onto the exposed GlcNAc.

In an alternative embodiment, the modified sugar is added directly to the peptide backbone using a glycosyltransferase known to transfer sugar residues to the peptide backbone. This exemplary embodiment is set forth in Scheme 14. Exemplary glycosyltransferases useful in practicing the present invention include, but are not limited to, GalNAc transferases (GalNAc T1-14), GlcNAc transferases, fucosyltransferases, glucosyltransferases, xylosyltransferases, mannosyltransferases and the like. Use of this approach allows the direct addition of modified sugars onto peptides that lack any carbohydrates or, alternatively, onto existing glycopeptides. In both cases, the addition of the modified sugar occurs at specific positions on the peptide backbone as defined by the substrate specificity of the glycosyltransferase and not in a random manner as occurs during modification of a protein's peptide backbone using chemical methods. An array of agents can be introduced into proteins or glycopeptides that lack the glycosyltransferase substrate peptide sequence by engineering the appropriate amino acid sequence into the peptide chain.

Scheme 14



In each of the exemplary embodiments set forth above, one or more additional chemical or enzymatic modification steps can be utilized following the conjugation of the

modified sugar to the peptide. In an exemplary embodiment, an enzyme (*e.g.*, fucosyltransferase) is used to append a glycosyl unit (*e.g.*, fucose) onto the terminal modified sugar attached to the peptide. In another example, an enzymatic reaction is utilized to “cap” sites to which the modified sugar failed to conjugate. Alternatively, a chemical reaction is utilized to alter the structure of the conjugated modified sugar. For example, the conjugated modified sugar is reacted with agents that stabilize or destabilize its linkage with the peptide component to which the modified sugar is attached. In another example, a component of the modified sugar is deprotected following its conjugation to the peptide. One of skill will appreciate that there is an array of enzymatic and chemical procedures that are useful in the methods of the invention at a stage after the modified sugar is conjugated to the peptide. Further elaboration of the modified sugar-peptide conjugate is within the scope of the invention.

Peptide Targeting With Mannose-6-Phosphate

In an exemplary embodiment the peptide is derivatized with at least one mannose-6-phosphate moiety. The mannose-6-phosphate moiety targets the peptide to a lysosome of a cell, and is useful, for example, to target therapeutic proteins to lysosomes for therapy of lysosomal storage diseases.

Lysosomal storage diseases are a group of over 40 disorders which are the result of defects in genes encoding enzymes that break down glycolipid or polysaccharide waste products within the lysosomes of cells. The enzymatic products, *e.g.*, sugars and lipids, are then recycled into new products. Each of these disorders results from an inherited autosomal or X-linked recessive trait which affects the levels of enzymes in the lysosome. Generally, there is no biological or functional activity of the affected enzymes in the cells and tissues of affected individuals. Table 5 provides a list of representative storage diseases and the enzymatic defect associated with the diseases. In such diseases the deficiency in enzyme function creates a progressive systemic deposition of lipid or carbohydrate substrate in lysosomes in cells in the body, eventually causing loss of organ function and death. The genetic etiology, clinical manifestations, molecular biology and possibility of the lysosomal storage diseases are detailed in Scriver *et al.*, eds., *THE METABOLIC AND MOLECULAR BASIS OF INHERITED DISEASE*, 7^{sup}.th Ed., Vol. II, McGraw Hill, (1995).

Table 5. Lysosomal storage diseases and associated enzymatic defects

Disease	Enzymatic Defect
Pompe disease	acid α -glucosidase (acid maltase)
MPSI* (Hurler disease)	α -L-iduronidase
MPSII (Hunter disease)	iduronate sulfatase
MPSIII (Sanfilippo)	heparan N-sulfatase
MPS IV (Morquio A)	galactose-6-sulfatase
MPS IV (Morquio B)	acid β -galactosidase
MPS VII (Sly disease)	β -glucuronidase
I-cell disease	N-acetylglucosamine-1-phosphotransferase
Schindler disease	α -N-acetylgalactosaminidase (α -galactosidase B)
Wolman disease	acid lipase
Cholesterol ester storage disease	acid lipase
Farber disease	lysosomal acid ceramidase
Niemann-Pick disease	acid sphingomyelinase
Gaucher disease	glucocerebrosidase
Krabbe disease	galactosylceramidase
Fabry disease	α -galactosidase A
GM1 gangliosidosis	acid β -galactosidase
Galactosialidosis	β -galactosidase and neuraminidase
Tay-Sachs's disease	hexosaminidase A
Magakaryotic leukodystrophy	arylsulphatase a
Sandhoff disease	hexosaminidase A and B

*MPS = mucopolysaccharidosis

De Duve first suggested that replacement of the missing lysosomal enzyme with exogenous biologically active enzyme might be a viable approach to treatment of lysosomal storage diseases (De Duve, *Fed. Proc.* **23**: 1045 (1964)). Since that time, various studies have suggested that enzyme replacement therapy may be beneficial for treating various lysosomal storage diseases. The best success has been shown with individuals with type I Gaucher disease, who have been treated with exogenous enzyme (β -glucocerebrosidase), prepared from placenta (Ceredase™) or, more recently, recombinantly (Cerezyme™). It has been suggested that enzyme replacement may also be beneficial for treating Fabry's disease, as well as other lysosomal storage diseases. See, for example, Dawson *et al.*, *Ped. Res.* **7**(8): 684-690 (1973) (*in vitro*) and Mapes *et al.*, *Science* **169**: 987 (1970) (*in vivo*). Clinical trials of enzyme replacement therapy have been reported for Fabry patients using infusions of normal plasma (Mapes *et al.*, *Science* **169**: 987-989 (1970)), α -galactosidase A purified from placenta (Brady *et al.*, *N. Eng. J. Med.* **279**: 1163 (1973)); or α -galactosidase A purified from spleen or plasma (Desnick *et al.*, *Proc. Natl. Acad. Sci., USA* **76**: 5326-5330 (1979)) and have demonstrated the biochemical effectiveness of direct enzyme replacement for Fabry disease.

These studies indicate the potential for eliminating, or significantly reducing, the pathological glycolipid storage by repeated enzyme replacement. For example, in one study (Desnick *et al.*, *supra*), intravenous injection of purified enzyme resulted in a transient reduction in the plasma levels of the stored lipid substrate, globotriasylceramide.

Accordingly, there exists a need in the art for methods for providing sufficient quantities of biologically active lysosomal enzymes, such as human α -galactosidase A, to deficient cells. Recently, recombinant approaches have attempted to address these needs, *see, e.g.*, U.S. Pat. No. 5,658,567; 5,580,757; Bishop *et al.*, *Proc. Natl. Acad. Sci., USA*, **83**: 4859-4863 (1986); Medin *et al.*, *Proc. Natl. Acad. Sci., USA*, **93**: 7917-7922 (1996); Novo, F. J., *Gene Therapy*, **4**: 488-492 (1997); Ohshima *et al.*, *Proc. Natl. Acad. Sci., USA*, **94**: 2540-2544 (1997); and Sugimoto *et al.*, *Human Gene Therapy* **6**: 905-915, (1995). Through the mannose-6-phosphate mediated targeting of therapeutic peptides to lysosomes, the present invention provides compositions and methods for delivering sufficient quantities of biologically active lysosomal peptides to deficient cells.

Thus, in an exemplary embodiment, the present invention provides a peptide according to Table 7 that is derivatized with mannose-6-phosphate (Figure 24 and Figure 25). The peptide may be recombinantly or chemically prepared. Moreover, the peptide can be the full, natural sequence, or it may be modified by, for example, truncation, extension, or it may include substitutions or deletions. Exemplary proteins that are remodeled using a method of the present invention include glucocerebrosidase, β -glucosidase, α -galactosidase A, acid- α -glucosidase (acid maltase). Representative modified peptides that are in clinical use include, but are not limited to, CeredaseTM, CerezymeTM, and FabryzymeTM. A glycosyl group on modified and clinically relevant peptides may also be altered utilizing a method of the invention. The mannose-6-phosphate is attached to the peptide via a glycosyl linking group.

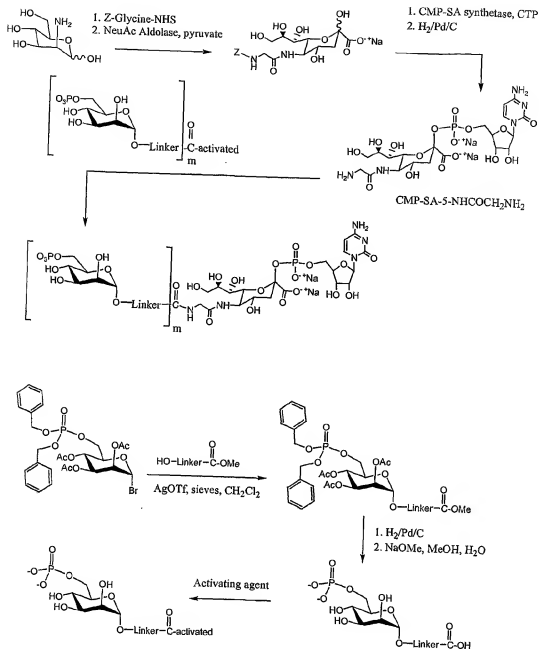
In an exemplary embodiment, the glycosyl linking group is derived from sialic acid. Exemplary sialic acid-derived glycosyl linking groups are set forth in Table 3, in which one or more of the "R" moieties is mannose-6-phosphate or a spacer group having one or more mannose-6-phosphate moieties attached thereto. The modified sialic acid moiety is preferably the terminal residue of an oligosaccharide linked to the surface of the peptide (Figure 26)

In addition to the mannose-6-phosphate, the peptides of the invention may be further derivatized with a moiety such as a water-soluble polymer, a therapeutic moiety, or an additional targeting moiety. Methods for attaching these and other groups are set forth herein. In an exemplary embodiment, the group other than mannose-6-phosphate is attached to the peptide via a derivatized sialic acid derivative according to Table 3, in which one or more of the "R" moieties is a group other than mannose-6-phosphate.

In an exemplary embodiment, a sialic acid moiety modified with a Cbz-protected glycine-based linker arm is prepared. The corresponding nucleotide sugar is prepared and the Cbz group is removed by catalytic hydrogenation. The resulting nucleotide sugar has an available, reactive amine that is contacted with an activated mannose-6-phosphate derivative, providing a mannose-6-phosphate derivatized nucleotide sugar that is useful in practicing the methods of the invention.

As shown in the scheme below (scheme 15), an exemplary activated mannose-6-phosphate derivative is formed by converting a 2-bromo-benzyl-protected phosphotriester into the corresponding triflate, *in situ*, and reacting the triflate with a linker having a reactive oxygen-containing moiety, forming an ether linkage between the sugar and the linker. The benzyl protecting groups are removed by catalytic hydrogenation, and the methyl ester of the linker is hydrolyzed, providing the corresponding carboxylic acid. The carboxylic acid is activated by any method known in the art. An exemplary activation procedure relies upon the conversion of the carboxylic acid to the N-hydroxysuccinimide ester.

Scheme 15



In another exemplary embodiment, as shown in the scheme below (scheme 16), a N-acetylated sialic acid is converted to an amine by manipulation of the pyruvyl moiety. Thus, the primary hydroxyl is converted to a sulfonate ester and reacted with sodium azide. The azide is catalytically reduced to the corresponding amine. The sugar is